THE ASSESSMENT OF THE PROBLEMS POSED BY HAZARDOUS WASTES IN LANDFILLS AND THE IDENTIFICATION OF REGULATORY CONTROL OPTIONS

Control options report

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January 25th, 1984 Project EO 83602

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Dear Mr. Burgess

Control Options Report

Enclosed please find ten copies of the final Control Options Report.

This final report incorporates all of the comments noted by Environment Canada and addresses the comments stated in your letter of January 16th, 1985.

This completes our involvement in this most interesting project and we thank you for your earnest contribution to both this report and the Problem Assessment Report.

Yours very truly

The Proctor & Redfern Group

W.D. Goodings, P. Eng.
Vice President

DS/ro
Attmt.

THE ASSESSMENT OF THE PROBLEMS

POSED BY HAZARDOUS WASTE IN LANDFILLS

AND THE IDENTIFICATION OF REGULATORY CONTROL OPTIONS

By

PROCTOR & REDFERN LIMITED

for the

WASTE MANAGEMENT BRANCH
ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA

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This unedited version is undergoing a limited distribution to transfer the information to people interested in the problem of disposing of hazardous wastes in landfill. This distribution is not intended to signify publication and, if the report is referenced, the author should cite it as an unpublished report of the Branch indicated below.

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Waste Management Branch
Environmental Protection Programs Directorate
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THE ASSESSMENT OF THE PROBLEMS POSED BY HAZARDOUS WASTES IN LANDFILLS AND THE IDENTIFICATION OF REGULATORY CONTROL OPTIONS

CONTROL OPTIONS REPORT

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January, 1985.

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1.0 INTRODUCTION

The purpose of this report is to describe the various control options available to the Federal and Provincial governments to develop and implement landfill controls and to identify which control option might be adopted. This follows a series of conclusions in the Problem Assessment Report which identified a number of reasons why regulatory controls should be developed for the disposal of hazardous waste by landfill. These included:

- there is a need for a uniform and consistent approach to hazardous waste landfill regulation development across Canada. Regulatory landfill controls would provide a minimum level of administration and prohibit inadequate and indiscriminate disposal,

- Federal initiatives in this area would motivate and support provinces in the development of landfill regulatory controls,

- the provinces have expressed their interest in obtaining from the Federal Government some technical assistance and advice in this field. The Federal government is in a position to provide this and channel the data and experience learned in some provinces to all provinces,

- landfill regulatory controls are required in order to minimize the potential for future negative impacts from continued landfilling of hazardous waste particularly in unsuitable locations or by means of unacceptable practices.

This report first provides the background to control option development by examining relevant experience in the United States and in some jurisdications in Europe. This review is considered essential, recognizing the advanced state of regulatory development in several jurisdictions outside of Canada, particularly in the United States. Following, various regulatory approaches and philosophies are examined in the context of the study objectives. These objectives include:

- the identification and evaluation of control options for implementation, roles and responsibilities, social, environmental, administrative and legal implications and cost-benefit effects resulting therefrom,

- the development of draft landfill list of regulatory controls for the establishment, operation, and perpetual care of hazardous waste landfill facilities,

- the description of an implementation framework in consideration of federal and provincial responsibilities and the preferred control option mechanism, be it guidelines, legislative statutes or a technical manual of good practice.

In approaching the issue of control options, a number of different concepts must be considered having regard for the following important questions:

- what is the environment that is to be protected?

- what are the contaminants that will be regulated?

- what is the activity that should be the subject of regulation?

The typical definition of 'the environment' is broad based in all provincial legislation, and includes air, water and land, and also social, health and often economic considerations. For the purposes of this report, 'the environment' will be defined as also having reference to social, health, and economic considerations.

A definition of hazardous waste has been developed by a Federal/Provincial-/Territorial working committee and is being adopted by the Federal government for use in the Transportation of Dangerous Goods Act. This definition is included in this report in Appendix A. It is important that a definition of hazardous waste and a comprehensive hazardous waste classification system be in-place to support regulatory control options.

The subject of this report is landfill disposal of hazardous waste and does not include waste piles, (industrial or otherwise), landfarming, lagoons or the like.

The protection of human health and the environment is the stated objective for developing landfill controls. Controls can be generally described as some form of legislative measure that regulates potentially harmful or undesirable conduct. In Canada the administration of controls which are regulatory based are normally a matter of provincial legislation, administration and enforcement, and landfill controls are no exception.

Legislative authority is an important consideration in addressing the objectives of this study and in developing the control options identified in Section 6 of this report. Certainly, it is not the intention of the Federal government to be involved in the treatment, disposal or regulation of hazardous waste. However, in view of the important nature of the matter and the Federal government's potential role in guiding and directing the provinces toward consistent standards insofar as hazardous waste management is concerned, this study is an appropriate Federal initiative.

2.0 THE UNITED STATES EXPERIENCE

The following section provides an overview of the United States' experience in hazardous waste landfill regulation, specifically the Resource Conservation and Recovery Act (RCRA). The history of regulation development, present landfill controls, and a discussion of future trends are all highlighted.

The purpose of reviewing the experience in the United States is as follows:

- landfill regulatory controls in the United States are the most comprehensive and advanced of any jurisdiction reviewed,

- the development of United States landfill regulations began in 1977. They are supported by considerable scientific background and technical studies,

- the current United States landfill regulations were developed after an extensive public consultation program. Input from all sectors of the government, industry, environmental groups and the general public is recognized in the regulations,

- the process of landfill regulatory control development in the United States progressed through a number of different approaches, regulatory options, and philosophies which are worthy of consideration by Canadians.

It is noteworthy that, unlike Canada, in the United States the ultimate responsibility for the management of hazardous waste rests with the Federal government. The authority vested in this mandate has permitted United States to proceed with comprehensive and all encompassing landfill regulations. Individual states have the delegated authority to administer the regulations under the auspices and direction of the Environmental Protection Agency, (EPA), a federal agency.

2.1 History of United States Hazardous Waste Landfill Regulations

The Resource Conservation and Recovery Act (RCRA) was enacted by the United States Congress in October 1976 to protect public health and the environment through the proper management of hazardous waste. RCRA was prepared to establish a 'cradle to grave' system for regulating hazardous waste from its source of generation, through storage and transportation, to treatment and disposal. RCRA directs EPA to prepare comprehensive regulations that would serve as minimum national standards for managing hazardous waste. Since 1976, many of these regulations have been issued under Subtitle C of RCRA.

Table 2-1 identifies the various sections prepared under Subtitle C of RCRA. These include regulations covering generation, transportation, treatment and disposal of hazardous waste.

Subsections 3004 and 3005 of subtitle C have particular application to the establishment and/or operation of a hazardous waste landfill facility and they:

- establish technical and environmental performance standards for landfill operations to protect human health and the environment,
- develop regulations and standards that govern the location, design and construction of existing and proposed hazardous waste landfill facilities,
- identify requirements for reporting, monitoring and inspecting hazardous waste landfill facilities,
- require the preparation of contingency plans in the event of accidental or sudden discharges from landfill facilities to the environment,
- establish permitting regulations including the form and content of information required in an application to establish a hazardous waste landfill,

TABLE 2-1

SUBTITLE C OF THE

RESOURCE CONSERVATION AND RECOVERY ACT

Section 3001	Identification and Listing of Hazardous Waste.
Section 3002	Standards Applicable to Generators of Hazardous Waste.
Section 3003	Standards Applicable to Transporters of Hazardous Waste.
Section 3004	Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.
Section 3005	Permits for Treatment, Storage, and Disposal of Hazardous Waste.
Section 3006	Authorized State Hazardous Waste Programs.
Section 3007	Inspection of Hazardous Waste Facilities.
Section 3008	Federal Enforcement of Hazardous Waste Standards.
Section 3009	Retention of State Authority.
Section 3010	Notification Procedures of Hazardous Waste Activities.
Section 3011	Authorization of Assistance to States.
Section 3012	Restrictions on Recycled Oil.
Section 3013	Monitoring, Analysis, and Testing of Hazardous Waste Facilities.

- identify requirements of ownership, continuity of operation, training of personnel and financial responsibilities of owners and operators of landfill facilities.

The development of landfill regulations in the United States began with study and data collection, then moved through the stages of formal rulemaking (i.e. proposal, comment and promulgation) followed by litigation, usually involving negotiation and a process often culminating in major revisions to the regulation. To enact a revision the process of formal rulemaking was again followed and often further litigation and negotiation was necessary. This seemingly endless iterative process was necessary considering the large number of policy issues, the amount of technical and scientific data, the range of specific items under consideration, and the underlying philosophies supporting each regulation. Table 2-2 is the chronology of RCRA landfill regulation development, including notable amendments. The most significant of these rulemakings was promulgated on July 26, 1982 when EPA established its current land disposal regulatory framework. Several amendments to these regulations have since been enacted but, the approach and philosophy are the same. The July 26, 1982 promulgations were preceded by the attainment of the milestones listed below:

- Proposed Regulations - December 18, 1978
- Phase I Regulations - May 19, 1980
- Phase II Regulations - February 5, 1981

.... followed by ....

- Promulgation - July 26, 1982.

Each of these milestones represented a major change in either the technical approach or philosophy of the regulation. Following a period of public review and comment, EPA made significant changes to the form and content of the proposed landfill regulations.

TABLE 2-2

CHRONOLOGY OF RESOURCE CONSERVATION AND RECOVERY ACT
LANDFILL REGULATION DEVELOPMENT

DATE	PAGE	PART NO.	TITLE AND/OR DESCRIPTION
Oct. 21, 1976	-	-	• Resource Conservation and Recovery Act (RCRA) enacted by the United States Congress amending the Solid Waste Disposal Act of 1965.
Dec. 18, 1978	58946	250	• Proposed National Standards for Location, Design, Operation, Monitoring, Closure and Post-Closure Care of Facilities which Treat, Store and Dispose of Hazardous Waste
May 19, 1980	33154	264, 265	• Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities • Subpart N - Landfills addresses general operating, closure and post-closure requirements in addition to special requirements for liquid wastes, containers and ignitable or reactive wastes
Oct. 8, 1980	66816	264	• Groundwater protection strategy proposed
Feb. 13, 1981	12414	122, 267	• Interim Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities and EPA Administered Permit Programs • Outlines temporary standards for landfills allowing issuance of permits to new land disposal facilities
Mar. 16, 1981	16897	122, 264, 265	• Standards for owners and operators of treatment storage and disposal facilities; Consolidated Permit Regulations
May 26, 1981	28314	264	• Standards applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities • Sets forth issues EPA considered in developing the standards and discusses risk assessment and various technical issues related to permitting hazardous waste landfills
May 28, 1981	28680	264, 265, 267	• Notes availability of and requests comments on various Technical Resource Documents (evaluating covers, landfills, liners, leachates, leachate management, stabilization, solidification, and closure)

TABLE 2-2

CHRONOLOGY OF RESOURCE CONSERVATION AND RECOVERY ACT
LANDFILL REGULATION DEVELOPMENT

DATE	PAGE	PART NO.	TITLE AND/OR DESCRIPTION
June 29, 1981	33502	265	• EPA amended regulations to allow the disposal of containerized liquid ignitable wastes in landfills until November 19, 1981
July 21, 1981	37527	264	• Extends comment deadline on landfill regulations from August 4 to October 4, 1981
July 31, 1981	39426	122, 262, 263, 264, 265	• Announces EPA's plan to eliminate the annual report, promulgate a uniform manifest, reduce Part B permit information based on a class of hazard approach and permits by rule. Also, announces EPA's intention to review operating record, ground water monitoring, financial and contingency plan requirements
Nov. 17, 1981	56592	265	• Amendment to allow disposal of certain small containers of liquid in landfills
Nov. 23, 1981	57284	264	• Amendments to Appendix VI, deletes requirement for geologic investigation where fault displacement and deformation are not significant
Feb. 25, 1982	8307	265	• EPA provides 90 day extension of the compliance date for prohibition of landfill disposal of containerized liquid waste and restrictions on landfill disposal of liquid ignitable waste
Mar. 22, 1982	12316	265	• Interim Final Rule banning landfill disposal of free standing containerized liquid
April 16, 1982	16544-16561	123, 264-5	• Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Liability Requirements; Revised Interim Final Rule
May 10, 1982	19995	264 - 5	• Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Financial Requirements. Correction notice to May 10, 1982.

TABLE 2-2

CHRONOLOGY OF RESOURCE CONSERVATION AND RECOVERY ACT
LANDFILL REGULATION DEVELOPMENT

DATE	PAGE		PART NO.	TITLE AND/OR DESCRIPTION
May 10, 1982	20008		262	• Hazardous Waste Management Systems; Standards for Generators, Transporters, Owners and Operators, Storage and Disposal Facilities; extension of comment period for proposed national uniform hazardous waste manifest
June 14, 1982	25546-2555		122 - 4	• Consolidated Permit Regulations; Revision in Accordance with Settlement; proposed rule making
June 24, 1982	27516-27519		122, 264	• Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Consolidated Permit Regulations
June 24, 1982	27520-27535		122, 264 - 5	• Hazardous Waste Management System: Standards for Generators of Hazardous Waste; Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Interim Final Amendments to Interim Final and Final Rules
July 13, 1982	30446-30447		264 - 5	• Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; Liability Coverage Requirements; Final Rule and notice of extension of effective date
July 26, 1982	32273-32373	PROMULGATION	122, 260 264 - 5	• Hazardous Waste Management System; Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; and EPA Administered Permit Programs; Permitting Requirements for Land Disposal Facilities Interim Final Rule with request for comments
July 26, 1982	32373-32378		123	• Requirements for Authorization of State Hazardous Waste Programs; Final Rule and Interim Final Rule with request for comments
July 26, 1982	32382-32384		264	• Hazardous Waste Management System; Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Interim Final Rule
July 26, 1982	32385-32388		265	• Hazardous Waste Management System; Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities; Notice of proposed rulemaking

TABLE 2-2

CHRONOLOGY OF RESOURCE CONSERVATION AND RECOVERY ACT
LANDFILL REGULATION DEVELOPMENT

DATE	PAGE		PART NO.	TITLE AND/OR DESCRIPTION
August 17, 1982	35706-35707	•	122, 260, 264 - S	• Hazardous Waste Management System; Notice of Public Meetings on Rule Land Disposal Standards (promulgated 7/26) and Development of RCRA Regulatory Reform Program
January 19, 1983	2514-2516	PROMULGATION	265	• Hazardous Waste Management System; Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; Proposed Amendment to Rule and Request for Comment, and Hazardous Waste Permit Program; Final Rule
	2506-2512		122, 260 264 - S	
January 28, 1983	3877-8		122, 262 264 - S,	• Hazardous Waste Management System; Standards Applicable to Generators of Hazardous Waste and Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
April 4, 1983	14472		260 - 1 264 - 6	• Hazardous Waste Management System: General; Identification and Listing of Hazardous Wastes; Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; and Standards for the Management of Specific Wastes and Management Standards for Specific Types of Facilities; Proposed Rule and Request for Comment
June 30, 1983	30113		124, 261, 264 - S, 270 - 1	• Hazardous Waste Management System: Permit Program Requirements for Authorization of State Programs; Procedures for Decision making; Identification and Listing of Hazardous Waste; Standards for Owners and Operators of Hazardous Waste Storage, Treatment, and Disposal Facilities; Interim Status Standards for Owners and Operators of Hazardous Waste Storage, Treatment, and Disposal Facilities; Correction; Final Rule
November 22, 1983	52718	•	265	• Hazardous Waste Management System; Interim Status Standards for Owners and Operators of Hazardous Waste, Treatment, Storage and Disposal Facilities; Clarification of the Scope and Applicability of the Interim Status Standards to Hazardous Waste Management Facilities; Final Rule

The proposed regulation released in December, 1978 was EPA's first attempt at establishing controls for hazardous waste landfill disposal. This proposal was based on strategy of total containment, which required all landfills to have a liner, leachate collection system and other design and operation controls to prevent the release (or escape) of leachate into the groundwater. The approach was to set uniform standards and design requirements for landfill facilities, subject to opportunities for variance when alternative designs could be proven to achieve equivalent environmental protection.

The containment approach was roundly criticized by industry in the ensuing comment period for various reasons:

- the failure to recognize that all liners may technically fail, to some degree,
- the regulations were not sufficiently flexible in terms of application and enforcement,
- the regulations were not oriented towards a common regulatory goal but were broad based in terms of protection to the environment and human health,
- there was a failure to apply any assessment that matched risks and benefits with costs and feasibility,
- there was a failure to recognize that landfill regulatory controls must reflect the 'degree of hazard' with regard to specific and unique landfill locations and situations.

In essence, EPA relied primarily on facility design and operation standards in developing the initial landfill regulations of December, 1978, although some performance standards (i.e. health and environmental standards) were incorporated to protect ground and surface water. In response to these comments, EPA scrutinized both the approach and the philosophy behind the proposed landfill regulations. Over the next two years the landfill regulations were reworked and finally released by the EPA as Phase 1 Regulations on May 19, 1980.

These Phase 1 Regulations were found to be incomplete and quite ambiguous by the public in that neither the approach nor the underlying philosophy had been finalized. The regulations included discussion on the merits of design and operation standards versus operation performance standards as two approaches to regulatory development. However, EPA stated that operation performance standards which place limits on releases, emissions, and the like, were implicit in many design and operation standards and could not be regarded as an exclusive approach. In these regulations EPA did direct that the Phase II Regulations should deal with all outstanding technical and administrative issues following review of comments on the Phase 1 approaches.

On February 5, 1981 EPA released the Phase II Regulations governing the design, operation and performance requirements for land disposal facilities. These regulations represented a major shift from the total containment approach that was suggested in the original proposed regulations of December 18, 1978. The Phase II regulations emphasized a predictive approach that would be based on a risk assessment specific to a particular landfill location. This approach required the permit writer, based on information and predictions submitted by the applicant, to evaluate the potential risks to human health and the environment posed by the location, design, construction and operation of the proposed landfill facility.

Due to the complexity of the proposed regulation and the importance of the issues involved, an extended comment period on the Phase II landfill regulations was provided. In May, 1981, EPA issued another notice which attempted to clarify several issues respecting the Phase II land disposal regulatory program. The issues cited in this notice included site-specific risk assessment, broad design standards, location standards, containment standards, and alternatives to land disposal. The notice also sought comment on a range of questions, such as what was the administrative burden likely to be imposed by various regulatory approaches and what was the likelihood of public acceptance of facilities permitted under different approaches. Many commented that a site-specific risk assessment approach was administratively too complex to implement and that insufficient scientific data were available on the health and environmental risks associated with the land disposal of specific hazardous wastes. In December, 1981, EPA held

public meetings to discuss the Agency's reappraisal of its regulatory approach and its change in philosophy that now considered the combined approach of groundwater protection standards plus design and operation standards for landfills.

In EPA's February, 1981 Phase II proposal of land disposal standards, the Agency was concerned about the lack of permitting standards for new land disposal facilities. The lack of these standards interfered with development, construction and operation of new environmentally acceptable facilities, and posed difficulties for new industrial facilities that relied upon on-site land disposal of hazardous waste. For the short term, EPA promulgated interim standards for four classes of new land disposal facilities. These were landfills, surface impoundments, land treatment units, and Class I underground injection wells. Based upon comments on this proposal and its subsequent May 26, 1981 notice, EPA concluded that a thorough review and modification of its regulatory strategy for land disposal of hazardous waste would be required. In order to integrate all the complex issues surrounding land disposal standards, EPA intended to promulgate these standards in the fall of 1983. However, in November, 1981, EPA was directed by a court order in **State of Illinois vs. Gorsuch** to promulgate regulations for existing hazardous waste land disposal facilities on or before February 1, 1982. This requirement then prompted the development of the land disposal regulations promulgated on July 26, 1982 and which are the basis of EPA's current position on hazardous waste landfill regulations.

2.2 Overview of United States Hazardous Waste Landfill Regulations

The regulations promulgated on July 26, 1982 apply to all proposed hazardous waste landfills in the United States. They consist primarily of two sets of standards: one (subparts K through N of U.S. 40 Code of Federal Regulations (CFR) Part 264), is a set of design and operation standards; the other (Subpart F) is a set of groundwater monitoring and 'corrective action response' requirements based on technical and environmental performance standards. The former set of standards is intended to protect the environment from the migration of leachate to adjacent subsurface soils, ground and surface waters. The latter standards are intended to ensure that owners or operators will detect any groundwater contamination and perform corrective action when such contamination threatens human health and the environment.

The design and operation standards require that all hazardous waste landfills have liners to prevent migration of waste through subsurface soil to ground and surface waters during the active life of the landfill facility. Landfill operators are also required to have leachate collection and removal systems to minimize the leachate remaining in the site after closure. A variance from the liner and leachate collection requirements is permitted only where owners or operators demonstrate that waste (leachate) from the landfill site will never migrate to the ground water or surface water.

Existing hazardous waste landfill operations are presently exempt from these requirements but are subject to reporting and permitting requirements. Landfills to be closed with the waste left in-place must apply final cover (capped) as a closure requirement. The landfill must then be maintained and monitored for groundwater contamination during the post-closure period. The length of the post-closure period is a site specific consideration which is subject to negotiation between the operator and the permitting agency.

It is intended that there will be further amendments to the July, 1982 rulemaking notice and refinements and improvements to the landfill regulations. This is noted in the preamble to the July, 1982 notices which state that the following would be developed:

- numerical criteria for certain design and performance standards, and ...
- specific standards that would be tailored to specific wastes, locations, and landfill management practices.

Table 2-3 summarizes the present hazardous waste landfill regulations (Subpart N) and the groundwater protection strategy (Subpart F) adopted by EPA. These regulations address design and operation standards, monitoring and inspection requirements, recordkeeping, closure and post-closure details and a special section that addresses matters such as the disposal of compatible and incompatible waste types. These regulations are complemented by the overall RCRA regulations and requirements for hazardous waste classification, permitting and the like.

In developing landfill regulations, EPA recognized that landfills potentially present two types of environmental problems:

- fires, explosions and generation of toxic fumes caused by improper handling of wastes, (i.e. operational problems due to improper materials handling or landfill operations),
- contamination of surface and ground waters due to off-site migration of waste resulting from any number of locational, design or operational based problems.

The management of hazards posed by problems of the first type is possible and the degree of risk can be significantly minimized. The second type of problem is much more difficult to manage. Therefore, EPA has directed that groundwater protection be a prime consideration in the establishment and operation of a hazardous waste landfill site.

The groundwater protection requirements contained in EPA's hazardous waste landfill regulations (as Subpart F, Part 264), established a three-stage program to detect, evaluate, and if necessary, correct groundwater contamination during the active and post-closure period of a facility.

TABLE 2-3

GUIDE TO SECTION 3004

**(Subparts N - Landfill, and
F - Groundwater Protection)**

**UNITED STATES RESOURCE
CONSERVATION AND RECOVERY ACT**

Section	Description	Regulation
SUBPART N - LANDFILLS		
264.300	Applicability	• applies to the disposal of hazardous waste in landfills.
264.301	Design and Operating Standards	• a landfill (except for an existing portion of a landfill) must have: - a liner installed to prevent any migration of wastes out of the landfill at any time (including closure period). It must be made of appropriate materials and installed carefully upon a supportive base, covering all areas likely to come into contact with water or leachate. - a leachate collection and removal system constructed of proper materials. A landfill may be exempt from this requirement if the owner can demonstrate that his design and operating practices will prevent migration of leachate. - a run-on control system must be maintained capable of handling peak discharge from at least a 25-year storm. - a run-off control system must be maintained to collect and control at least the water volume from a 24-hour, 25-year storm.

Section	Description	Regulation
264.301	Continued	- collection and holding facilities must be managed. - wind dispersal of wastes must be controlled.
264.302	Double-lined Landfills. Exemption from Subpart F groundwater protection requirements	• the owner/operator of a double-lined landfill is not subject to regulation under Subpart F if the following conditions are met: - the landfill is located entirely above the seasonal high water table. - the landfill is underlain by two liners to prevent migration of liquids. - a leak detection system is maintained. Appropriate action must be taken if a leak is detected.
264.303	Monitoring and Inspection	• during construction and installation, immediately after construction and installation, and during operation, liners must be inspected.
264.309	Surveying and Record-keeping	• the operating record must maintain information including a map showing the exact location and depth of each cell and the contents of each type of hazardous waste within each cell.
264.310	Closure and Post-closure Care	• at closure of the landfill, a final cover must be designed and constructed to: - minimize migration of liquids - require little maintenance - promote drainage and minimize erosion - accommodate settling/subsidence so that the cover's integrity is maintained - minimize infiltration.

Section	Description	Regulation
264.310	Continued	• post closure requirements include: - maintenance of integrity of final cover - in the case of double liners, maintain/monitor leak detection system - maintain leachate collection system until it is no longer detected - maintain and monitor the groundwater monitoring system - prevent run-on and run-off - protect and maintain surveyed benchmarks
264.312	Special Requirements for Ignitable or Reactive Wastes	• these wastes must not be placed in a landfill unless they have undergone treatment which renders them no longer ignitable or reactive. • ignitable wastes in containers may be landfilled if they are disposed in such a way that they are protected from any material or condition which may cause them to ignite.
264.313	Special Requirements for Incompatible Wastes	• incompatible wastes must not be placed in the same landfill site.
264.314	Special Requirements for Liquid Wastes	• landfilling of bulk or non-containerized liquid wastes containing free liquids may only take place in landfills designed for such or must be treated or stabilized so that free liquids are no longer present.
264.316	Disposal of Small Containers of Hazardous Waste in Overpacked Drums (Lab Packs)	• these may be placed in a landfill if: - the waste is packaged in non-leaking containers, - the containers are overpacked in open head DOT specification metal shipping containers, - the absorbent material used is non-reactive, - wastes are compatible within each container, - reactive wastes are treated prior to packaging.

Section	Description	Regulation
SUBPART F - GROUNDWATER PROTECTION		
264.90	Applicability	• applies to owners and operators of facilities that treat, store, or dispose of hazardous waste in surface impoundments, waste piles, land treatment units or landfills. • owner/operators may be exempt under certain conditions.
264.91	Required Programs	• a monitoring and response program must be conducted when: - hazardous contaminants are detected at the compliance point (a compliance monitoring program must be instituted) - the groundwater protection standard is exceeded (a corrective action program must be instituted) - hazardous constituents exceed concentration limits in groundwater between the compliance point and the downgradient facility property boundary (a corrective action program must be instituted) • in all other cases, a detection monitoring program must be instituted • the facility permit will specify the specific elements of the monitoring and response program required.
264.92	Groundwater Protection Standard	• the hazardous constitutents entering the groundwater must not exceed the concentration limits in the uppermost aquifer underlying the waste management area beyond the point of compliance during the compliance period.

Section	Description	Regulation
264.93	Hazardous Constituents	• the permit specifies the hazardous constituents to which the groundwater protection standard applies. • exemptions of hazardous constituents from the list specified in the facility permit may be granted by the Regional Administrator taking into consideration potential adverse affects on groundwater quality, hydraulically-connected surface water quality and any underground sources of drinking water.
264.94	Concentration Limits	• the facility permit will specify the concentration limits in the groundwater. • if a constituent does not pose a hazard at the defined level, an alternate concentration limit may be established.
264.95	Point of Compliance	• the facility permit will specify the point of compliance at which the groundwater protection standard applies. • the point of compliance and waste management area are defined.
264.96	Compliance Period	• the facility permit specifies the compliance period during which the groundwater protection standard applies. • the compliance period is defined.
264.97	General Groundwater Monitoring Requirements	• describes the requirements which must be complied with for any groundwater monitoring program.
264.98	Detection Monitoring Program	• sets out responsibilities for the owner/operator in the establishment of a detection monitoring program.

Section	Description	Regulation
265.99	Compliance Monitoring Program	• the responsibilities for an owner/operator required to establish a compliance monitoring program are described.
265.100	Corrective Action Program	• the minimum responsibilities for an owner/operator required to establish a corrective action program are set out.

The first stage of the groundwater monitoring and response program is the detection monitoring program, which requires the permittee to install a groundwater monitoring system at the waste boundary (including upgradient and downgradient of wells) to monitor groundwater for parameters that would indicate whether a leachate plume has reached the waste boundary or is moving away from the landfill site.

If a leachate plume is detected, the second stage, a compliance monitoring program, is enacted. The compliance monitoring program requires that hazardous waste constituents reasonably expected to be in or derived from a waste disposal facility be identified and that concentration limits be established. Each of these specific constituents are then regularly sampled for in the groundwater. These results are then compared against the established groundwater protection standards or concentration limits. The compliance monitoring program requires that hazardous constituents not exceed the established concentration limits. These established concentration limits are normally based on well established numerical concentration limits (i.e. drinking water standards). However, if no established numerical standards exist, then concentration limits are based on existing groundwater quality background levels.

Other elements of the compliance monitoring program include establishing the point of compliance and the compliance period. The point of compliance is the location at which the groundwater protection standard applies and at which monitoring must be conducted. The compliance period is usually equal to the active life of the landfill plus the post-closure period.

If a groundwater protection standard or concentration limit is violated, the third stage (corrective action) is initiated. Corrective action must continue until the groundwater standard is met. Corrective action could consist of removing contaminates (by pumping or other means), or by in-situ treatment of the hazardous constituents. Regulations provide an option whereby owners or operators may comply with a more stringent set of design and operation standards and obtain a waiver from groundwater monitoring and response requirements. These special standards include two bottom liners (instead of a single liner generally required for new facilities) and a leak detection system between the liners. This

requirement is in addition to the leachate collection and removal system above the liners that is required for all new landfills in the United States. If a leak is discovered, the damaged liner must be repaired or replaced, or the owner/operator will become subject to the groundwater monitoring response requirements.

2.3 Current Hazardous Waste Landfill Practices Relative to RCRA Regulatory Development

Hazardous waste landfill regulations in the United States are primarily concerned with the protection of ground and surface waters. As such, current landfill practices are concerned with the management of liquids and attention is focussed on methods and practices to control the production and migration of leachate. This is achieved in the design and operation of a hazardous waste landfill site by:

- controlling surface run-on and run-off. Run-on control is intended to minimize leachate production by keeping liquids out and away from active portions of the landfill. This also prevents surface discharge of wastes in solution or suspension and controls erosion.

  Run-off includes rainwater, leachate or any other liquid that drains over land from active portions of the landfill. This run-off has a high probability of contamination and must be controlled and collected. This is accomplished by preventing the disposal of liquid wastes in the landfill, minimizing exposed areas of active landfill operations and providing physical separation between active and unused areas of the landfill site.

  Existing regulations require run-on and run-off control structures to be sized to a 25-year storm event. However, EPA recommends that these systems should be designed to accommodate a storm event relative to the actual operating life of the landfill.

- placing a liner(s) beneath the waste to prevent the migration of leachate and to facilitate the collection and removal of leachate. All landfill sites in the United States that dispose of hazardous waste are required to install liners, constructed of materials that will prevent wastes from passing into and through the liner. Synthetic or flexible membrane liners are presently the only materials that will meet these specifications.

With respect to liner construction and standards, EPA has established the following guidelines:

- liner systems are to be constructed above the seasonal high water table within the unsaturated zone to prevent liner rupture that may occur with seasonal freeze-thaw cycles,

- a single flexible membrane liner (FML) should provide containment of leachate for at least 30 years. Therefore, a single FML system is suggested for landfill cells which will receive final cover in less than 30 years and a double FML for landfill cells that will remain open longer than 30 years,

- liners need to be at least 30 mils thick to assure the material has sufficient strength and thickness to prevent failure due to physical stress. The liner should also be constructed of materials that resist degradation,

- soil-clay liners should have no sand lenses, cracks, channels, root holes, or other structural deficiencies that would increase the nominal hydraulic conductivity of the liner above 1×10^{-7} cm/sec. and be at least 60 centimetres thick for stability reasons. Where compacted, emplaced secondary clay liners are used, they should be constructed in lifts not exceeding 15 centimetres to ensure effective compaction and moisture content,

- have a piped system for leachate collection and removal which minimizes hydraulic pressure on the liner and reduces the quantity of leachate in the fill. Current design practice is to have at least a 30 centimetre drainage layer with a hydraulic conductivity of not less than 1 x 10^{-3} cm/sec. and a minimum slope of 2 percent.

  The leachate collection system should have a drainage tile system of appropriate size and spacing to minimize liquid transmission through the liner system and facilitate the collection and removal of leachate. Experience in the United States indicates that a liner system design incorporating 10 centimetre diameter tiles at 15 to 60 metre centres will effectively minimize the head on the liner system and permit leachate collection.

  The pipe material used in the leachate collection system must be of suitable material and of sufficient strength to effectively perform during the active and post-closure periods of landfill operation. The material of selection is typically a flexible conduit such as plastic or fibreglass due to the corrosive nature of leachate.

- prohibiting the disposal of liquids by landfill. The practice of disposal of free liquids in containers, by regulation, is no longer considered a viable landfill disposal technique. Liquids in containers must be decanted or solidified (mixed with absorbent) so that no free liquids are present. If there is a question whether free liquids remain, the operator may perform a 'free liquids' test. This test involves the use of a paint filter in which a portion of the waste is placed for a given time. If liquids emerge from the filter bottom within the given time, the wastes may not be landfilled without further treatment.

- prohibiting the disposal of partially full or empty containers of hazardous waste in a landfill. The container must be either 90 percent full or crushed prior to disposal. The purpose of this practice is to minimize subsidence of the final cover of the landfill resulting from the decay of partially full or empty containers.

- prohibiting the direct disposal of ignitable, reactive and other incompatible wastes unless treated or protected from material or conditions which would cause these wastes to react or ignite.

- establishing closure and post-closure requirements that address final cover and perpetual care and monitoring. The approach to closure in the United States involves the placement of a three-layer final cover on each cell preferably as landfill operations progress. The final cover is the key element in the overall strategy of liquids management and containment. The three layer final cover approach includes:

  - the top layer of approximately one metre of soil that would accommodate vegetation at a 3 percent minimum slope,

  - the second drainage layer, approximately 30 centimetres thick and constructed of porous material (at least 1×10^{-3} cm/sec.) to accommodate major sustained storm events,

  - the third layer which functions as an impermeable barrier to any liquid. This layer typically consists of two components; a synthetic liner and a secondary clay cap of approximately one metre thickness at a maximum hydraulic conductivity of 1×10^{-7} cm/sec.

  By regulation, post-closure care must be continued at a hazardous waste landfill site for at least 30 years after closure. Post-closure care includes maintaining the integrity of the final cover, regular monitoring and site inspections.

The traditional method of hazardous waste land disposal in the United States prior to the enactment of RCRA was co-disposal which is essentially the practice of disposing of hazardous and non-hazardous wastes together. The development of strict design and operation standards for hazardous waste landfill disposal and the designation that any non-hazardous waste when mixed with a hazardous waste results

in the entire mixture being classified as hazardous has restricted the practice of co-disposal in the United States.

However, the use of landfill for the management of hazardous waste remains the most frequently used disposal method. A recent study of hazardous waste generation and disposal in the United States found that[1]:

- approximately 3 million tonnes of hazardous waste were disposed of by off-site landfill facilities in 1981. This represents about one percent of total hazardous waste generated in the U.S.,
- about 46 percent of the 430 hazardous waste management facilities in the United States used landfills for hazardous waste disposal during 1981,
- approximately 96 percent of hazardous waste generated in the U.S. (264,000,000 tonnes per year) is managed at the site of generation.

The EPA has suggested that hazardous waste be disposed of by two methods: the secure landfill as dictated by RCRA landfill regulations as previously described in this report, and by monofills. Monofills are landfills used to store or dispose of one or more of a small group of organic wastes. This includes wastes that are hazardous solely because they exhibit the characteristic of EP toxicity. This means that a particular waste will leach certain metals and other hazardous constituents in significant quantities when placed in an acid environment. This group of wastes is further restricted to wastes that would not leach significant quantities of constituents in the absence of an acid leaching medium. In July 1982, EPA identified a group of wastes which may meet the above criteria and could be disposed in regulated monofills. These wastes include:

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1 Westat Research, Inc., 'National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981', April, 1984.

- incinerator ash;
- residuals from foundry furnace emissions control;
- metal casting molding sand;
- hydroxide and carbonate sludges resulting from treatment of plating bath wastes;
- residuals from titanium dioxide production;
- oven residues from the production of chrome and oxide green pigments; and
- emission control dust or sludge from the production of steel.

Standards for the establishment and operation of monofills have yet to be published by EPA and are not expected in the near future. Until that time, their establishment and operation is regulated under Subtitle C, Sub-Part N - Landfills.

In summary, EPA has expended considerable time and resources in developing landfill regulations. This approach involved a comprehensive public consultation program that solicited comments from industry, environmental groups and interested citizens and government. The result is a comprehensive set of landfill regulations based on a philosophy that considers both performance (technical and environmental) standards and design and operation standards. This approach was adopted by the U.S. because the two types of regulatory standards provide a more complete guide to landfill establishment and operation relative to the objective of protecting human health and the environment. In recognition of these efforts, attention must be given to EPA regulations in the development of a landfill regulatory control option for Canada.

2.4 Emerging Hazardous Waste Management Policy in The United States

The July, 1982 RCRA regulations became effective within six months after the announcement in the Federal Register. At that time EPA announced that other regulatory actions would be initiated including:

- promulgating standards for specific hazardous wastes based on degree of hazard studies. These studies will examine the disposal of various combinations of waste by volume, treatment and disposal technologies and environmental settings.

- establishing financial requirements for owners and operators of hazardous waste landfill facilities including demonstrating financial responsibility for corrective standards.

Each of these initiatives is in various stages of preparation and there is no indication of when this information will be presented for public comment. Since that time, EPA has also undertaken various background studies that may eventually lead to promulgation of other hazardous waste landfill regulations. These initiatives address many of the issues of landfill management and include:

- groundwater protection is an important EPA policy initiative. The Agency is investigating a number of proposed policies respecting groundwater protection objectives and monitoring requirements. The most recent EPA draft policy suggested that the requirements and objectives of groundwater protection be considered in regard to the class of underlying aquifer. Five different classes were identified including special aquifers, current drinking water sources, potential drinking water sources, potential but unlikely drinking water sources and aquifers that will never be used for drinking water purposes.

  It is premature to suggest that this approach represents a shift in the EPA approach to groundwater protection since at present there is no indication on the future direction of this initiative,

- preparation of standards for hazardous waste disposal by monofill,

- on February 15, 1984, EPA announced that regulations to restrict or prohibit land disposal of certain hazardous wastes were being developed. In support of this initiative, EPA is conducting studies that will determine which hazardous wastes are the most toxic, mobile, persistent and bioaccumulative in certain environments and situations. This may result in EPA ranking hazardous wastes for landfill disposal, and possibly specifying pre-treatment standards,

- conducting on-going research and development in several other unspecified areas related to hazardous waste disposal by landfill.

It, therefore, appears that the future trend in the EPA approach to hazardous waste landfill development is primarily in the areas of improvement and refinement of the current hazardous waste landfill regulations. Changes in approach or philosophy are not currently being considered and the July, 1982 regulations would seem to dictate future policy with respect to landfill disposal of hazardous waste in the United States.

3.0 OVERVIEW OF INTERNATIONAL EXPERIENCE

The issue of hazardous waste management has received considerable attention internationally. Many international working groups have been established and Canada has been an active participant. These working groups have addressed a wide range of matters including the disposal of hazardous waste by landfill.

A report by NATO/Committee on the Challenges of Modern Society (CCMS) Pilot Study on the Disposal of Hazardous Wastes is one of many documents prepared on the subject by international interests1. This report provides an overview of hazardous waste landfill disposal practices in several NATO countries, identifies research projects of participating countries and provides several conclusions. Although this report is somewhat dated (1977) many of the conclusions still have relevance to this study:

- the disposal of hazardous waste by landfill represents an important method of disposal primarily because few alternative management methods exist,

- landfill is regarded as one of a number of hazardous waste management components in the overall strategies developed by participating countries,

- continued use of landfill for hazardous waste disposal is generally accepted. However, because of site specific considerations in siting, design and operation, it may not be possible to identify a single management approach for general use,

- the protection of groundwater and surface water resources is considered an important objective in selecting and operating a hazardous waste landfill,

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1 North Atlantic Treaty Organization, 'Disposal of Hazardous Wastes - Landfill', No. 64, May, 1977.

- the advent of legislation to regulate hazardous waste landfill disposal will provide more effective controls and minimize the possibility of problem sites,

- co-disposal of hazardous waste is not considered appropriate for wastes with recovery potential or for particularly hazardous wastes.

As part of the data collection exercise, a number of European countries were contacted with respect to current regulations and existing landfill disposal practices. This information is summarized in Table 3-1 and for each country as follows:

- in the Federal Republic of Germany, responsibility for the management of hazardous waste is at the state level. Several of the states have integrated treatment and disposal facilities in-place including secure landfill facilities. The disposal of hazardous wastes by landfill is regulated in all of the states with respect to the type and nature of waste which can be deposited. Appendix B provides a summary of landfill guidelines prepared by the Federal government for regulation at the state level. These guidelines provide design and operation standards for the selection, design, construction, operation, rehabilitation, and perpetual care of landfill sites. Although not specifically directed towards hazardous waste landfill operations, these guidelines are suitably broad to include both conventional and secure landfill operations. Containment and collection of leachate is the preferred management approach adopted in West Germany.

- In Sweden, the disposal of hazardous waste by landfill is being increasingly regulated. A country-wide system for hazardous waste management is being developed, for which landfill is an important support component. At present, hazardous wastes are co-disposed but for the most part, are solidified and deposited in above-ground landfills (depones). No regulations or guidelines were received from Sweden.

- In the United Kingdom, landfill is a predominant method of hazardous waste disposal. It is estimated that 90 percent of 'controlled' wastes are disposed of by landfill. Pre- treatment of some wastes by solidification occurs, but typically both hazardous and liquid wastes are landfilled directly.

  The regulation of landfill operations is carried out at the regional level on a site specific basis. Certain hazardous waste types are discouraged from being landfilled but the decision to dispose of particular wastes by landfill is considered with regard to individual site characteristics. The practice of leachate management by attenuation rather than by containment and collection, is normally practiced. This requires that particular attention be given to the natural and hydrogeologic setting of a potential hazardous waste landfill location.

  The rehabilitation and perpetual care of landfill sites has received considerable study in the United Kingdom. These studies have resulted in the establishment of programs for post-closure groundwater monitoring. Further, procedures for evaluating the applicability of various end use alternatives in conjuction with remedial measure engineering are currently being developed.

- The landfilling of hazardous and liquid industrial waste in The Netherlands is strictly prohibited. The availability of land and the presence of a high water table throughout the country limit the use of landfill for both hazardous and non-hazardous waste disposal. As a result, other methods of hazardous waste management, including export to other countries are utilized.

  An extensive landfill identification and remedial works program is being undertaken in The Netherlands to correct the problems at an estimated 350 problem sites. These problem sites resulted from the indiscriminate dumping of hazardous waste in the past.

- The disposal of hazardous waste in France utilizes 13 controlled landfill sites in addition to a number of privately owned and operated treatment facilities. Solidification and de-watering of sludges is commonly undertaken prior to disposal by landfill. The attenuation approach to leachate management is common practice at landfill sites located in suitable hydrogeological settings. Otherwise, leachate is collected and then treated by physical/chemical methods.

  Landfill regulations or guidelines were not available from France.

- Belgium is presently developing a country-wide system for the management of hazardous waste. There are no landfill sites currently licenced to receive hazardous wastes although co-disposal practices occur. A considerable amount of hazardous waste generated in Belgium is exported to other European countries for treatment and disposal.

The European approach to disposal of hazardous waste by landfill varies considerably from country to country. Although international working groups have addressed the matter, there is no concensus of approach regarding design philosophy or management strategy. Many of the hazardous waste landfill sites in Europe rely on attenuation of leachate and suggest that the hydrogeological suitability of a site is the paramount consideration. Countries such as Germany, with available alternatives to landfill disposal, have the ability to develop and enforce landfill guidelines.

Essentially the European approach has been progmatic and has been a process of compromise recognizing industry concerns, the cost of alternative management approaches and the cost of environmental remediation. Comprehensive guidelines have not been established in the same manner as the U.S. and it is suggested that the attention to the U.S. approach would be more beneficial to the Canadian situation.

TABLE 3.1

EXISTING REGULATIONS AND GUIDELINES OUTSIDE CANADA

COUNTRY	REGULATIONS AND GUIDELINES	RESPONSIBILITY FOR WASTE MANAGEMENT	HAZARDOUS WASTE LANDFILL DISPOSAL PRACTICE
FEDERAL REPUBLIC OF GERMANY	• federal legislation to deal with 'special wastes' was created in 1972 in the form of the Waste Disposal Act • included in the Act are waste definitions, collection, transportation, siting, management and licencing requirements. Three categories of industrial wastes are identified in the regulations • in 1981, the Federal Environment Agency established guidelines for 'Controlled Landfilling of Waste.' This does not deal specifically with hazardous waste, but many of the items would likely also apply to hazardous waste landfilling.	• in national and international matters the Ministry of the Interior has responsibility for waste management • regionally, each of the 10 Landers or States, has a separate environment department which implements and enforces the Waste Disposal Act.	• integrated treatment and disposal facilities have been established by public and quasi-public agencies in several states • secure landfill is fundamental to each hazardous waste management system • type and nature of hazardous waste disposed by landfill is regulated
SWEDEN	• in 1975, legislation was enacted to create a crown agency, Svensk Avfallskonvertering AB (SAKAB), to be owned by the Department of Agriculture, Swedish Municipal Union, and the Waste Treatment Disposal Fund • the National Swedish Environment Protection Board lists 10 hazardous waste categories	• authority for waste management lies with the Department of Agriculture and the National Swedish Environment Protection Board • SAKAB has sole responsibility for the treatment, disposal and export of wastes.	• above ground landfill disposal practiced • hazardous and liquid wastes usually solidified prior to landfill
UNITED KINGDOM	• two federal acts regulate hazardous wastes in the United Kingdom: The Deposit of Poisonous Waste Act (1972) and The Control of Pollution Act (1974). Control of Pollution (Special Waste) Regulations were established in 1980. • the latter set out licencing and approvals procedures, and established the manifest system	• according to the Control of Pollution Act, each county level Waste Disposal Authority must develop a waste management plan for their jurisdiction • land disposal sites are dealt with individually and are controlled by site licencing requirements set out on a case-by-case basis	• approximately 30 privately owned, licenced landfills operate on a commercial basis within the United Kingdom • a 1972 survey of 3,000 landfill sites in the country which at some time received hazardous wastes, concluded that only 50 of the sites might present a possible hazard to a major aquifer. 19 of these sites received detailed investigation • 90 percent of all 'controlled wastes' in England are deposited at landfills

TABLE 3.1

EXISTING REGULATIONS AND GUIDELINES OUTSIDE CANADA

COUNTRY	REGULATIONS AND GUIDELINES	RESPONSIBILITY FOR WASTE MANAGEMENT	HAZARDOUS WASTE LANDFILL DISPOSAL PRACTICE
NETHERLANDS	• The Ministry of Public Healthand Environmental Prutection administers the Chemical Waste Act (1976) which was implemented in 1979 • included in the Chemical Waste Act are licencing requirements and establishment of the manifest system and review to industries generating waste. A Schedule to the Substances and Processes decree lists waste streams • a Chemical Substances Bill was put before the Lower House of Dutch Parliament in 1981	• The Ministry of Public Health and Environmental Protection oversees waste management	• landfilling of chemical wastes is prohibited in the Netherlands by an Act of Parliament • a lack of suitable lands and a high water table limit the use of landfill in general • landfilling of hazardous waste is allowed only in the presence of strict special conditions • a government survey (1980) of uncontrolled sites revealed that 4,000 such sites exist. Remedial work is in progress at some of 350 sites which were identified as requiring action • it is preferred that landfilling be performed above ground level rather than in excavations or depressions
FRANCE	• The Waste Disposal and Resource Recovery Act (1975) contains a listing of wastes considered to be harmful and, therefore, requiring special treatment or disposal, licencing requirements and statements encouraging reuse, recycling and reclamation • The Pollution Control Division of the Ministry of the Environment controls waste management in France. Licencing of facilities is carried out by the Bureau of Mines Regional Offices. Permits are issued on the basis of guidelines established by the Industrial Environment Branch of the Ministry of the Environment • a memorandum of January 22, 1980 regarding landfilling of special industrial waste establishes criteria for site selection, conditions under which waste is accepted, and the facilities and supervision required.	• The Pollution Control Division of the Ministry of the Environment controls waste management • waste generators are required to manage their wastes in an environmentally acceptable manner	• most treatment and disposal operations are privately owned • approximately 13 controlled landfills currently operate in France with additional sites to be opened in the future • a National Agency for Waste Recovery and Disposal (ANRED) exists which assists in the setting up of facilities for the processing and use of waste, and encourages the development of new techniques. The state-owned public service can provide financial and technical aid through funds obtained from the Ministries of the Environment and of Industry and Research • solidification of wastes practiced extensively

TABLE 3.1

EXISTING REGULATIONS AND GUIDELINES OUTSIDE CANADA

COUNTRY	REGULATIONS AND GUIDELINES	RESPONSIBILITY FOR WASTE MANAGEMENT	HAZARDOUS WASTE LANDFILL DISPOSAL PRACTICE
BELGIUM	• specifications for permit application and operation of landfills 1982 • waste control law established in July 1981	• a legislative and research body (OVAM) for waste control in Flemish region was founded in October 1981 to assist in the enforcement of waste control law	• no hazardous waste landfill sites are licenced • several licences for disposal of inert industrial waste have been issued • some hazardous wastes exported

4.0 REGULATORY CONTROL PHILOSOPHIES

The approach taken to managing the disposal by landfill of hazardous waste is directed by the underlying philosophy to regulation, design and operation and is based on a number of factors that are often specific to a jurisdication. For example, the philosophy of prohibition of landfill in the Netherlands results from the unavailability of suitable locations for a landfill and the experience with past landfill practices. Other jurisdictions may not face the same constraints as the Netherlands, but nonetheless consider other factors in developing a regulatory control philosophy:

- existing technical and scientific data which often conflicts from one jurisdiction to another and is continually being expanded, updated and refined,

- public interests and industry pressure,

- availability of alternative methods of hazardous waste management,

- past experience with hazardous waste landfill practices. This is an important consideration since the development of regulatory controls is often initiated in response to a problem. In jurisdictions where no widespread or significant health or environmental impacts have been identified, an approach such as natural attenuation is more generally acceptable. Other jurisdictions have adopted the approach that future environmental risks that may be associated with a particular philosophy greatly outweigh any short term economic benefits,

- the type, quantity and nature of hazardous waste requiring management.

The management approach taken results in the type of regulatory standard adopted. The natural attenuation approach is typically regulated by performance standards whereby other approaches typically consider one or more types of regulatory standards in developing a landfill control option.

Few of the jurisdictions reviewed for this study, have opted for an approach which considers more than one manner or philosophy of approach. This section of the report describes the regulatory standards used in other jurisdictions in the context of landfill design and operation and the management approach taken. All are shown on Table 4-1, and include:

REGULATORY STANDARD	MANAGEMENT APPROACH
• performance standards (technical and environmental)	• containment, collection and treatment
• design and operation standards	• controlled release and natural attenuation
	• risk assessment (degree of hazard)

TABLE 4.1

COMPARISON OF ALTERNATIVE REGULATORY STRATEGIES

REGULATORY APPROACH	DESCRIPTION	EXAMPLE	ADVANTAGES/DISADVANTAGES
Design and Operating Standards	- Standards that require specific equipment or use of a particular technique	liner specification such as x feet of clay with a permeability of 10^{-9} cm/second	• does not permit flexibility in application • considered too specific to allow for unique site specific characteristics • provides for complete regulatory control
Technical Performance Standards	- standards that establish an engineering objective and require that the design and operation achieve that objective	requirement to develop a storm water management plan to accommodate a specified storm event	• permits flexibility and innovation in choice of technology and design • considered relatively cost-effective as alternatives can be examined • allows for site specific consideration
Environmental Performance Standards	- standards that specify limits (usually numerical) on levels of contamination that will be tolerated in the environment	groundwater quality standards for groundwater below a facility	• measure of flexibility in application • often requires use of imperical standards due to lack of scientific data • permits evaluation based on all factors • allows for site specific considerations
Containment Approach	- requires that waste or waste constituents be kept within a certain area for a fixed period of time	a liner standard requiring that the liner be able to contain waste for x years	• in theory a positive objective • zero leakage not considered attainable • long term impacts not specifically addressed
Risk Assessment Approach (degree of hazard)	- broad narrative criteria which assists in a site specific assessment of risk and in developing conditions of of approval. - based on evaluations of the hazard potential of wastes and the identification of relationships between potential hazard and health and environmental effects	a standard which requires the proponent to demonstrate that there will be no significant risk of health resulting from establishment of a landfill	• more suited to proposal assessment than facility regulation • degrees of hazard sometimes subjective and usually non-quantitative
Controlled Release Approach	- consideration of the natural hydrogeological setting for attenuation and dilution of leachates	ground and surface waste quality as measured at the property limit must not exceed X times drinking water standards	• a realistic approach to regulation development that considers the use of all types of standards • is suited to risk assessment • flexible approach

REGULATORY STANDARDS

4.1 Performance Standards

Generally, two types of performance standards have been considered in developing hazardous waste landfill regulations by other jurisdictions; technical and environmental.

Technical performance standards identify engineering performance objectives to which specific design parameters can be applied to achieve a stated objective. A typical example is the establishment of a 25-year storm criteria. The response in terms of technical performance would be to design a stormwater management system with the capability to handle a 25-year storm occurrence. A technical performance standard is based on the degree of risk relative to the ability of available technology to achieve an objective.

The application of technical performance standards permits a flexibility in design and the choice of technology. This approach is considered to be relatively cost-effective since design alternatives and innovative approaches are considered in terms of cost as well as technical capability. As such, technological innovation is encouraged because the environmental standard or objective rather than a specific design type or set of design criteria is specified. The 25-year storm criteria establishes a standard which can be achieved in several ways, but requires that the engineered design and operation of the facility consider technical performance, available technology and site specific conditions. Compliance is ensured through the establishment of a regular monitoring program.

Environmental performance standards specify a maximum or a range of limits that must be met to protect the environment and human health. These are typically identified in terms of risk specifications for health or in consideration to established pollutant control objectives. A good example is the establishment of drinking water standards or water quality criteria which establish the maximum limits of performance compliance.

The appraisal of what constitutes an acceptable (or unacceptable) environmental performance objective requires that an evaluation of the combined potential effect of all factors on the environment be assessed. Typically, this includes consideration of the hydrogeological characteristics of a particular site with respect to the type and characteristics of waste that will be deposited, proposed engineered design and method of operations and the assumed quality, quantity and transport of expected contaminants from the landfill site and the existing and possible future use of resources (i.e. ground and surface water) in the site influence zone. Often empirical limits are assigned because of the lack of scientific data.

The development of technical and environmental performance standards require that a full account of the application be considered in relation to a number of site and application specific factors including[1]:

- the nature and characteristics of the waste destined for disposal. Factors such as toxicity, biodegradability and incompatibility of waste would be determined,

- the site hydrogeology which governs the rate and direction of contaminant transport through the soil and groundwater (i.e. the potential pathways),

- the potential for attenuation of contaminants by geotechnical interactions with geologic materials,

- the potential release rate of unattenuated pollutants to surface and/or ground waters,

- the character of the receiving ground and surface waters, including the establishment of background quality levels and concentrations,

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1 Cartwright, et al, 'Geological Considerations in the Hazardous Waste Disposal', Journal of Hydrology, Vol. 54, pp. 357-368, 1981.

- an inventory of the surrounding environs including population distributions, flora, fauna and the interrelated uses of these environs,

- the proposed landfill design and operation procedures.

If performance standards are established on a general use basis and without regard for site specifics, it is possible the standards might be unworkable in terms of application and enforcement. The premise in establishing performance standards is to permit flexible application with consideration to unique circumstances. That is not to say that technical or environmental objectives should vary by application, but rather that the method and nature of the response to a particular performance objective should recognize all relevant factors and the interaction of those factors.

Performance standards are particularly applicable when considering alternative design philosophies such as controlled release and attenuation. However, in practice, it is difficult to determine or predict environmental effects on the basis of assumed leachate and migration characteristics. What is usually substituted in place of predictive effects are established standards such as water quality criteria. However, these established criteria may or may not have application to a particular environmental objective or standard. Again, consideration must be given to the particular site and surrounding environs.

Technical and environmental performance standards form a large part of EPA hazardous waste landfill standards, particularly with respect to the protection of groundwater. These were chosen with consideration to a number of factors, but primarily because of their flexibility of application and adaptability to several approach philosophies.

4.2 Design and Operation Standards

Design and operation standards form the basis of landfill regulatory controls adopted in many jurisdictions. These types of standards differ from performance standards in that specific practices or equipment are specified to meet a number of stated environmental and technical objectives. Design and operation standards are specific in nature and allow for little flexibility in application or in regard to unique site specific characteristics. A typical example of a design and operation standard is the specification for liner design which firstly requires the type of liner and secondly, specifies the maximum allowable permeability of the liner.

Design and operation standards provide considerably more regulatory control than do other types of standards. However, in practice the implementation of design and operation standards sometimes results in rigid enforcement and complex design features. This critical assessment must be viewed in light of the relatively short history of hazardous waste landfill practices and the uncertainty in predicting impacts. With ultimate regard to protection of the environment, the 'over design' of landfill facilities may not be questionable. However, design and operation standards have also been criticized for discouraging the advance of technology, innovative engineering design and significantly increasing the cost of hazardous waste landfill establishment and operation.

Design and operation standards do have the advantage of providing specific requirements or design criteria which can be understood and interpreted by both the permit writer and the applicant. They are, therefore, considered enforceable.

Regulatory standards are established primarily to protect human health and the environment. Depending solely on one approach has limitations, particularly with respect to flexibility of application and the need to recognize site specific circumstances. Recognizing that the U.S. approach was to adopt both performance and design and operation standards, similar consideration should be given in the establishment of a Canadian regulatory control option.

MANAGEMENT APPROACHES

4.3 Risk Assessment Approach

A risk assessment approach estimates the degree of hazard of a proposed undertaking and the associated risk on human health and the environment. Following this assessment, a necessary level of protection can be established in terms of health and environmental safeguards.

Risk assessment standards are developed in consideration of acceptable risk levels that serve to reduce the probability of adverse impacts. This requires that degrees of hazard be established for each waste type and assessed in relation to the characteristics of a proposed site and location. Further, long and short term effects are considered in this assessment.

Often models are used to predict potential effects and estimates of risk often depend on the population density in the vicinity of the landfill site. Therefore, areas of low population density would normally receive lower risk estimates than areas of higher population density. However, population density by itself is a poor indicator of individual or population risks. Actual risks depend on where and how releases of hazardous constituents move through the environment, the ultimate fate of the waste and most importantly, the exposure received by a particular individual or segment of the population. These type of effects are difficult to predict considering the current state of scientific data available.

Risk assessment approaches often attempt to compare risk benefits and costs for different management options. Generally, four standard approaches to risk assessment are used[1]:

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1 U.S. Congressional Office of Technology Assessment, 'Technologies and Management Strategies For Hazardous Waste Control', March, 1983.

- relative risk assessment in which the risk estimate of one option (or location) is compared to another,

- risk benefit assessment whereby risks and expected benefits are estimated and compared for options. The objective of this approach is to maximize benefits and minimize risks. Cost-benefit analysis is a similar approach except that costs are used to compare risks and benefits,

- cost-effectiveness approach which establishes an acceptable level of risk and compares the cost of each option with respect to selecting the most cost effective option.

The form of a risk assessment standard that has so far resulted is a general, broad, narrative criterion which is more applicable to undertaking a site specific assessment than in regulating landfill site selection, design and operations. Many of the risk assessment objectives are inherent in the development of other types of landfill standards and regulatory approaches often combine, say a risk assessment approach with performance standards.

An example of a risk assessment standard is that a proposal will not pose a significant risk of cancer to a population. Certainly, any landfill standard would have regard in the regulation for this type of concern and would reflect this type of standard in an environmental performance standard. It was on this basis that EPA did not consider the use of a risk assessment standard as the sole approach in developing U.S. hazardous waste landfill guidelines. Rather, the risk assessment approach was considered in developing environmental standards for landfill performance.

4.4 Total Containment Approach

The total containment approach requires that hazardous waste and the resulting waste constituents disposed of by landfill be confined within a certain area for a specified period of time.

In theory, the containment approach would isolate waste within the landfill and have a release rate of zero during the active life of the site and near zero over the long term. In practical terms, total containment will not result in zero releases over an indefinite period of time and any hazardous waste landfill presents some long term risk in terms of migration of wastes from the site. It is, therefore, important to consider both natural and artificial containment measures in the selection and design of a hazardous waste landfill site.

Fundamental to a total containment type of landfill site are the liner characteristics, leachate management system and the final cover. The liner, either natural (i.e. clay) or synthetic, is a single or multi-barrier impediment to leachate migration and facilitates the collection of leachate. Leachate is typically collected by one or more series of underdrains. Selection of liner and collection pipe materials is important and must consider the nature and type of waste to be deposited.

Final covering of a completed landfill site is a necessary containment function in order to prevent excess water from entering the site. In combination with the proper stormwater management, these features will minimize the production of leachate and potentially minimize off-site impacts.

The United States Environmental Protection Agency reviewed the total containment approach but rejected it following due consideration that technical performance could not be ultimately attained. However, the philosophy of containment is the basis for the U.S. landfill regulatory standards which require leachate to be collected and removed.

4.5 Controlled Release Approach

The controlled release of leachate from a landfill is a management strategy used extensively in the United Kingdom and to a lesser extent, in Canada, the United States and other European countries. Historically, municipal landfill sites (dumps) were operated on this basis but without regard for the hydrogeological setting and without knowledge of potential environmental or health impacts.

In the controlled release approach, natural attenuation and dilution occurs as leachate produced at the landfill site percolates through the underlying soil. The hydrogeology of the site is fundamental to this design and must provide:

- constant release of liquid from the bottom of the site to prevent significant mounding of leachate within the landfill,
- protection against the contamination of ground and surface waters through slow vertical and horizontal migration of leachate from the site,
- the ability to attenuate and contain contaminants.

Landfills designed on the basis of the controlled release approach are typically located in areas of deep, slowly impermeable soils. Further, these sites are usually situated away from areas of surface water and flood prone areas. Leachate collection systems are often employed to regulate the release of liquids from the fill and to provide an engineered back-up or contingency system.

Particular attention must be given to the characteristics of waste deposited in landfills where there is a controlled release into the environment through the ground and then through the surface and ground water. Generally, liquids, organic wastes and extremely hazardous wastes are pre-treated prior to disposal or managed by other methods.

The controlled release approach is often considered with regard to environmental performance standards. For example, in the design of a site for which the controlled release approach will be used, an environmental performance standard would typically be applied to ensure the maintenance of ground or surface water quality[1]. This recognizes an environmental performance requirement and permits the designer to establish a buffer zone and leachate release rate that will recognize the site characteristics and the controlled release approach.

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1 This type of environmental performance standard is almost always established by a jurisdiction that permits the use of buffer areas for leachate management. EPA standards do not permit degradation of water quality to more than ten times drinking water quality standards as measured at the property line. The Ontario Ministry of the Environment has established general guidelines for in-house use such as the 25/50 guidelines. Health related parameters cannot exceed 25 percent of background levels at the site property line and non-health parameters cannot exceed 50 percent of background levels at the site property line.

5.0 OPTIONS DEVELOPMENT

5.1 Landfill Regulatory Control Development

The review of other jurisdictions such as the United States and Europe has demonstrated that a comprehensive hazardous waste management system will not develop unless its basic requirements are prescribed and enforced by legislation. This legislation must have due regard for a number of considerations when developing regulatory controls for hazardous waste landfill such as:

- acceptable and available alternatives to treat and dispose of hazardous waste,
- existing legislation and the ability to enforce,
- respective government roles and responsibilities,
- the scientific and technical data base necessary to establish and support legislation.

The following section provides a list of proposed landfill control guidelines based on the above considerations. The purpose of this list is to initiate discussion between the Federal and Provincial governments on the merits of different regulatory approaches and philosophies, to provide direction to the preparation of overall landfill guidelines and to stimulate the development of landfill regulatory controls at the provincial level.

The development of landfill controls for the disposal of hazardous waste by landfill should consider several objectives:

- to ensure the maximum protection of health and environment,
- to encourage alternatives to land disposal of hazardous waste,

- to define and classify those hazardous wastes acceptable for disposal by landfill,
- to reduce and eliminate the costs to society of long term management of inactive or abandoned landfill sites,
- to consider the long term along with the short term hazards and risks posed by landfilling of hazardous waste,
- to alleviate public resistance to the establishment and operation of modern and competent hazardous waste landfill sites,
- to ensure effective approaches to the management and monitoring of hazardous waste landfill operations,
- to select an approach to regulation development which is both effective in achieving environmental protection as well as being readily implementable and enforceable,
- to provide standards that are technically feasible, cost effective, and attainable,
- to encourage research and development efforts that will expand on the existing technical and scientific data base.

The following Table 5-1 provides a list of landfill control guidelines applicable to hazardous waste landfill disposal and listed with respect to Federal and Provincial roles and responsibilities. These control guidelines are necessarily general rather than numerical in nature as they are suggested guidelines to the selection, design and operation of a hazardous waste landfill. The guidelines stress technical performance as the primary gauge of the adequacy of the standard. This approach represents a commitment in the guildelines to protecting environmental and social concerns.

For example, one suggested control guideline is the technical standard that all hazardous waste landfills have an adequate liner system. This guideline necessarily avoids defining the type, permeability, function, or nature of the liner system required. This is because it is the intent that those guidelines described in Table 5-1 be used as the basis for stimulating the development of numerical standards to effectively regulate hazardous waste landfill disposal at the provincial and territorial level. It is suggested that regulatory controls could be developed by the Federal government in consultation with the provinces and the public. The process should also follow Federal guidance in the assessment of social, economic, environmental and other impacts of the proposed control option.

We believe that there should be a degree of flexibility in the resultant Federal landfill control guidelines since landfills each have unique settings. The control guidelines should set out the concerns and perforance standards to be met. Individual or site specific application of these guidelines would result in landfill proposals that would be sited, engineered and operated in a specific way, presumably to meet these concerns and established performance standards. The merit of this approach is that good planning and engineering practice is applied rather than blindly following rules without regard to performance.

This flexibility does present some drawbacks to the regulator as well as the proponent. The absence of specific and numerical guidelines places considerable authority with the regulator in terms of conditions of approval, criterion evaluation and operating parameters. However, since we believe that the development of hazardous waste landfill regulatory controls will continue at the provincial level using the federal guidelines, the controls presented herein are designed to be minimum design and operation standards within the context of the Federal mandate. In view of these existing mandates, the guidelines are identified as being either a Federal or Provincial responsibility. This division recognizes the Federal role of providing consistency and technical guidance and the provincial role of implementation and enforcement of regulations.

The landfill controls guidelines presented in Table 5-1 are not based on a single management or regulatory approach. Rather, for the purposes of future discussion, a range of considerations are presented. This is necessary because of the various stages of regulation development or nondevelopment that is presently the situation in the provinces. The experience in the United States indicates that landfill controls must be supported by comprehensive waste management legislation which deals with all issues including hazardous waste definition and classification, transportation, generator and owner standards and the like. (Section 2.0 of this report). Without these necessary and complementing regulations, landfill controls are virtually unenforceable. Therefore, the controls suggested herein go beyond those pertaining to and directed at landfilling only. For instance, if the types and nature of hazardous waste permitted to be disposed of by landfill is to be regulated, then the classification of hazardous waste is essential to identifying acceptable or unacceptable wastes. It is apparent that landfill controls cannot stand alone, but must be supported and complemented by comprehensive and broader based hazardous waste legislation and regulation.

Controls considered necessary for the safe landfilling of hazardous wastes are presented under the following general categories:

- regulatory controls which deal with the administrative and permitting aspects of hazardous waste landfill establishment,

- environmental controls which seek to provide minimum performance standards to protect the environment, particularly ground and surface water resources,

- technical controls which provide minimum design and operation standards, for hazardous waste landfills,

- social controls which attempt to ensure the protection of human health. It is important to realize that the use of risk assessment estimates may be useful in considering each of the suggested guidelines,

TABLE 5.1

HAZARDOUS WASTE LANDFILL
CONTROL GUIDELINES
ITEMS FOR CONSIDERATION

SUGGESTED FEDERAL ROLE	PROVINCIAL ROLE
REGULATORY	
• Proposals to establish and operate a hazardous waste landfill site will be subject to public and regulatory scrutiny including the requirement of a public hearing	• To provide the necessary legislation to effect public and regulatory review of all proposals
• To specify environmentally and technically feasible methods of hazardous waste disposal by landfill (i.e. secure, co-disposal and monofill)	• To establish standards for the design and operation of monofills and other acceptable alternatives to secure landfill
• A permit is required for the operation of a hazardous waste landfill site	• To establish a permitting process accessible and understandable to perspective applicants
• Approval permits will be reviewed on a regular basis	• To specify maximum life of available permit and frequency of review
• Wastes which can be treated or detoxified by other management methods or recycled will not be permitted to be landfilled.	• To establish the type and nature of wastes acceptable for disposal by landfill by establishing a waste definition and classification list that reflects disposal options. To prepare a definition of waste type disposal compatibilities.
ENVIRONMENTAL	
• Ground and surface water resources must not be degraded beyond National Drinking Water Standards	• Contamination must not exceed level x at point y for contaminant z
• Groundwater protection guidelines	• To establish a groundwater policy
• Hydrogeological setting of proposed sites must be suitable and provide a maximum level of natural protection	• To identify hydrogeological siting parameters including minimum acceptable ranges of permeability
• Potable water resources must not be affected and drinking water guidelines should be established.	• To develop policy and/or guidelines which identify drinking water quality standards
TECHNICAL	
• All sites are required to install a liner between waste and natural soil to prevent migration (or escape of wastes to soils, ground or surface water	• To certify acceptable liner materials and develop liner permeability, structural integrity, thickness, design and operating standards
• Liners should be installed to provide maximum protection for the longest period of time	• To establish liner site life requirements
• Leachate produced at the site must be collected and adequately treated	• To specify the minimum level of efficiency for leachate management including material selection, design criteria and operational standards
• Stormwater, run-on and run-off must be managed	• To establish storm event criteria, design and monitoring standards.
• A ground and surface water monitoring program must be established	• To establish program parameters, include method and frequency of monitoring

TABLE 5.1 (Continued)

SUGGESTED FEDERAL ROLE	PROVINCIAL ROLE
SOCIAL	
• The establishment of a landfill site must not impact on individuals, communities or services • The site must not impact on the health/welfare of residents • Adequate buffer zone must be established to maintain and protect adjacent land uses	• To establish a site selection guideline to ensure that all factors are considered • To identify a risk assessment approach including updating of the data during the life of the site • To establish buffer zone requirements
OPERATING	
• The direct disposal of ignitable, reactive and incompatible wastes will be prohibited from landfill sites • The disposal of liquids by landfill is not permitted • The disposal of empty containers by landfill is prohibited • Hazardous wastes require pre-treatment prior to disposal by landfill • Hazardous waste landfill operations must be regularly inspected with regard to operating specifications and conditions of approval • Maintenance and contingency plans must be prepared that address unusual and unique situations including accidents • Staff must be properly trained and supervised in all aspects of hazardous waste landfill operations	• To define and classify hazardous wastes by characteristic and specifically identify those wastes unsuitable for disposal by landfill • To establish prohibitive legislation and prepare a definition of liquid including testing procedures • To enact appropriate legislation defining acceptable and non-acceptable waste types • To specify concentrations of hazardous wastes permitted and identify incompatible waste lists • To establish regular inspection program using qualified staff trained and familiar in landfill operations • To establish the considerations to be addressed in these plans and a review and approvals mechanism for implementation • To design and organize landfill training programs in consultation with other provinces or the federal government.
CLOSURE/POST CLOSURE	
• Completed landfill cells and the site must be capped in a suitable manner to prevent infiltration • The final landfill cap must be maintained • Post closure monitoring of the landfill must be perpetual • Perpetual care funds must be established during and after site operations • Proponent liability for sudden and non-sudden discharges must be guaranteed • Technical proof of environmental impairment is sufficient to release cleanup or remedial funds. Legal proof in the strictest sense is not required. (i.e. no onus upon the alleged damaged property to prove damage).	• To develop final cover permeability and design criteria (i.e. materials, design specifications,etc.) • To specify the type of uses permitted during post-closure and identify restricted uses for x years following closure • To specify the minimum number of years for which post closure must be undertaken • To establish lines of post closure responsibility • To establish perpetual care program including contribution requirements • To prepare regulations requiring owner/operators to have insurance • To prepare administrative mechanisms to authorize the undertaking of of remedial measures.

- operating controls which prescribe minimum management standards that are primarily directed towards ultimate protection of the environment and human health,

- closure and post-closure controls that provide design standards and environmental performance objectives that seek to ensure the protection of the environment through the long term integrity of the landfill site after operations have ceased.

A major consideration in developing guidelines for the regulation of hazardous waste disposal by landfill was to provide a series of controls which were flexible in terms of interpretation and administration. They were to provide for consideration of unique characteristics of a proposed landfill site, to be readily understandable by both proponent and regulator and to provide a specified degree of protection to the environment and human health.

A major emphasis of the guidelines presented in Table 5-1 is the protection of groundwater resources. A separate groundwater strategy is not spelled out but should be as regulations evolve. Classification of groundwater resources is also not addressed but could be considered in the development of a groundwater strategy.

5.2 Cost-Benefit Evaluation

The development and implementation of hazardous waste landfill regulatory controls will probably be undertaken and administered at the provincial level. Therefore, the associated costs and benefits of action vs. no-action are not quantified at the Federal level except when considering the associated cost impacts on establishing or upgrading Federal landfill facilities.

However, it is appropriate to examine the overall effect of implementing regulations and considering the net positive (or negative) effects of environmentally acceptable landfill practices. For the purposes of the cost-benefit assessment, the assumption is that continuation of existing hazardous waste landfill practices will result in significant direct and indirect costs for site remedial measures, health care and the like. The effect of implementing regulatory controls is that these costs may be avoided or significantly reduced.

In the assessment of costs and benefits, one approach is to compare the costs of 'doing it right' with 'doing it wrong'. That is to say, what is the cost of establishing a hazardous waste landfill site on the basis of the best technology and design features available versus the cost of having to undertake site remedial works and establish compensation funds when a landfill site impacts on surrounding environs.

In order to provide a quantifiable measure of 'doing it right' versus 'doing it wrong', which is the basis for this limited cost-benefit evaluation, the following was undertaken having consideration to experience in the United States:

- gross approximations of per unit capital and operating costs for hazardous waste landfill site development and for remedial action measures at problem sites were prepared utilizing existing literature sources,

- several specific examples of remedial landfill site actions were examined to identify works and associated costs. Since there are few Canadian examples, the United States 'Superfund' program was used as the primary source of information,

- the cost of establishing, developing, and operating a dedicated hazardous waste landfill site in Canada was estimated on the basis of state-of-the-art design parameters,

- an evaluation of these costs was undertaken and the incremental differences between 'doing it right' versus 'doing it wrong' was identified,

- these incremental differences were then considered in terms of order of magnitude.

No attempt was made to interpolate these data on the basis of Canadian hazardous waste generation estimates or to existing problem site clean-up requirements. Insufficient information is available to undertake this type of assessment.

Appendix C provides some background information to the establishment of costs for remedial or cleanup measures at problem sites and the design assumptions and associated costs of establishing a dedicated hazardous waste landfill site.

It should be noted that the costs identified in Appendix C and utilized in the cost and benefit evaluation are applicable only for comparison purposes and are gross estimates of an order of magnitude. Each situation is different and these cost estimates must be viewed accordingly.

The basic conclusion of the cost benefit evaluation is that it is more cost effective in the long term to incur significant short term landfill development costs than it is to pay for remedial works in the future that may include compensation for health and environmental effects.

Numerous examples in the United States suggest that there is significant cost to undertake problem landfill site remedial work. Love Canal, in Niagara Falls, New York for example has already incurred over $36 million ($U.S.) in clean-up costs. Ultimate costs for remedial action has been estimated at $100 million ($U.S.) with some estimates as high as $1 billion ($U.S.)[1]. These estimates do not include compensation and claims resulting from lawsuits for which about $2 billion ($U.S.) has so far been claimed.

It has been estimated that to clean-up the majority of the 15,000 uncontrolled waste disposal sites in the United States, $18 to $40 billion ($U.S.) will be required. Again, this estimate includes only those known problem landfill sites and does not consider associated compensation or legal claims[2].

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1 Office of Technology Assessment, 'Technologies and Management Strategies for Hazardous Waste Control', March, 1983.

2 Ibid

Individual problem site clean-up costs vary widely depending on the nature of the remedial work required. For example, a landfill site located in Seymour, Indiana will require about $22.7 million ($U.S.) for clean-up costs and another site in St. Louis, Missouri will require at least $38.5 million ($U.S.) to undertake remedial work. The U.S. EPA has estimated that the cost of groundwater clean-up at these sites to range from $5 to $10 million ($U.S.) per site with total restoration of the contaminated aquifer to be in the order of 10 times that cost[1]. Other problem sites where the situation is primarily local and potential impacts are considered signficantly less threatening to human health and the environment, are restored from $100,000 to $500,000 ($U.S.). A recent clean-up operation at an illegal dump site in King Township, Ontario, has so far cost almost $800,000 to remove hazardous wastes and take certain remedial actions.

EPA has estimated that remedial works and cost of clean-up at a problem site to be in the order of $2,000 per tonne ($U.S.). In comparison, proper disposal in compliance with EPA standards and regulations is estimated to be about $90 per tonne ($U.S.)[2]. This figure, however, may be low due to its reliance on the current regulations. While the regulations are intended to protect human health and environment, it is not necessarily a guarantee that it would do so. In effect, the $90 per tonne ($U.S.) can be considered to be the minimum cost for proper disposal and may rise with an increased level of regulatory protection. It can be concluded, on the basis of the experience in the United States, that no matter what the level of protection afforded, the costs for 'proper' landfill disposal is unlikely to reach the cost for clean-up of 'improper' landfill disposal.

Appendix C provides further information on remedial costs and hazardous waste landfill development costs. These costs are prepared as a per unit cost per hectare and reflect a number of assumptions based on a theoretical situation.

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1 Office of Technology Assessment, 'Technologies and Management Strategies for Hazardous Waste Control', March, 1983.

2 United States Environmental Protection Agency, 'Handbook - Remedial Action at Waste Disposal Sites', June, 1982.

This exercise suggests that on the basis of a cost and benefit evaluation and considering both quantifiable and non-quantifiable factors, 'doing it right' is significantly more cost effective than 'doing it wrong'.

5.3 Social Impact Assessment

Federal government policy requires that a socio-economic impact analysis (SEIA) be prepared for most major regulations related to health, safety or fairness (HSF). It is necessary, not only to assess potential social and economic impacts, but to address the adequacy of, and available alternatives to, proposed regulatory control. The preceeding Section 5.2 developed an overview of the cost benefit component whereas this section describes the social impact component of a SEIA.

A social impact assessment (SIA) is prepared to describe and predict potential and allocative effects on human resources resulting from a proposed undertaking. Although it is not the intent of this report to prepare a SIA, it is necessary to identify the role of the SIA in the landfill regulatory development process and provide an indication of how this process can be applied to assessing the promulgation of certain landfill regulatory controls.

The basis of a SIA is identifying the human resources potentially effected and assessing the degree of risk or hazard potentially imposed on these resources. This is typically prepared by utilizing a number of non-quantifiable and often surrogate indicators or measures. For example, a common social impact indicator used is the potential effect on real estate values in the community or area of a proposed hazardous waste landfill operation. This indicator suggests a potential monetary effect but fails to describe potential impact in terms of individual income effect. Further, the actual social effect of this situation can only be presumed.

In assessing the establishment of landfill regulatory options, it can be generally concluded that a properly designed and operated hazardous waste landfill site should have less effect on property values than an existing problem landfill site.

However, this incremental difference in cost is difficult to quantify and more difficult to translate as a cost or human impact on the community or personal level.

Cost-benefit analysis can provide a systematic attempt at measuring in monetary terms relevant social costs and benefits. However, this approach is typically a broad brushed one when assessing social impacts, and often fails to assess monetary impacts at the level of an individual or family. More importantly, this approach does not identify non-quantifiable impacts or estimate degrees of risk associated with an undertaking.

There are several other limitations to using the cost-benefit approach to evaluate the social impact of establishing regulatory controls. These include:[1]

- in the area of health, safety and fairness, impacts and benefits cannot always be reduced to a monetary value,

- the estimation of benefits from a regulatory control is difficult when it involves uncertainty as to the extent of reduced social impacts on human resources.

Therefore, it seems appropriate that if a SIA of proposed landfill regulatory controls is undertaken, then a set of specific factors should be developed that are oriented towards the potential impact of hazardous waste landfill disposal. Table 5-2 provides a list of social impact considerations that are based on:

- identifying the extent of social, health, economic and environmental impact on human resources at the community, adjacent land owner and individual level that might be expected in absence of the regulatory controls,

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1 Treasury Board Canada, 'Administrative Policy Manual, Chapter 490, Socio-Economic Impact Analysis', June, 1982.

- identifying the extent of risk to human resources associated with doing nothing,

- identifying the positive aspects and benefits of landfill regulatory development,

- identifying the range of human resources that should be assessed.

The social impact considerations identified in Table 5-2 could also provide a benchmark for assessing the social adequacy of a hazardous waste landfill operation. It is recommended that this list be further refined and described in conjunction with the landfill regulatory control development.

The considerations outlined in Table 5-2 are prepared on the basis that, in the absence of landfill regulatory controls, there will be an increasing level of social impact. Conversely, the establishment of landfill regulatory controls will lessen this impact and negative community and individual perceptions of potential landfill impacts. As such, it is submitted that an SIA should be undertaken to assess the relative changes in the quality of life resulting from the promulgation of regulatory controls.

TABLE 5-2

SOCIAL IMPACT CONSIDERATIONS

LANDFILL REGULATORY CONTROL DEVELOPMENT

HUMAN RESOURCE	POTENTIAL IMPACT			
	SOCIAL	HEALTH	ECONOMIC	ENVIRONMENTAL
Community	• change in municipal population • change in number of people who perceive community is a good place to live • change in municipal services • change in transportation system • change in recreational facilities, greenery and open space • change in resources of archaeological/cultural/historical/scientific value	• change in health care costs and services • change in related health care incidents • change in related emergency/accident situations • change in death and birth rate per 1,000 population • change in related occupational health incidents	• valve added per worker for landfill support services • change in employment • change in municipal mill rate • opportunities lost - mineral/aggregate resources	• change in air pollution index • change in municipal drinking water supply • change in wildlife habitat, migratory patterns, abundance and diversity of species • change in number of complaints related to environmental problems or incidents
Surrounding Land Owners	• number of families perceiving a change in living conditions and privacy • change in number of residences opposing landfill operation • number of families realizing a change in nuisance impacts - noise, vibration, dust, odour, views • change in level of municipal services - water, sewer, etc. • changes in local roads, number of vehicles using roads and access considerations • change in number of accidents in area • number of residents displaced or moving from area • changes in area land uses - number and type	• change in health related incidents in area • change in quality of potable water sources • change in number of chronic health incidents • change in births and deaths • change in number of incidents related to exposure to waste, odours, etc.	• change in the average valve of buildings and land • change in agricultural productivity on a unit basis • change in number of agricultural operations • change in assessment and property taxes	• change in number of environmentally related incidents - spills, accidental discharges • change in number of observable problems in area - odours, vegetation kills/stress, water degradation, etc.
Individual	• number of people perceiving a change in the quality of life • number of people bothered by excess noise, odour, aggravation • number of active opponents to landfill operations • number of people identifying change in daily living routine.	• change in number of people requiring health care - chronic and accidental • number of people perceiving change in level of health and environmental risks • number of people reporting change in personal discomfort	• change in personal incomes • number of people wanting but unable to relocate due to financial constraints • change in value of real estate as a % of personal income	• change in perception of what is an environmentally acceptable landfill practice • change in number of people utilizing surrounding or immediate environs

6.0 REGULATORY ROLES

This section identifies the potential roles and responsibilities of the Federal and provincial governments with regard to initiating and developing landfill controls (i.e. the control options). An implementation framework is also discussed, particularly with regard to the Federal social economic impact analysis (SEIA) and public consultation procedures.

Generally this section poses the following questions and provides discussion based on existing legislative mandates, and the practicality and feasibility of various roles:

- should the Federal government get involved in hazardous waste landfill regulatory control development?,
- if yes, in what manner or role should the Federal government participate?,
- how should landfill regulations be implemented, administered and enforced?,
- should the implementation be unilateral or in consultation with the provinces?,
- can the Federal government assist during the period of transition?

It is also important to question why are landfilling regulatory controls required and what is the value of complementing legislation? The Problem Assessment Report provided several reasons for the development of Federal landfill guidelines useful for the development of provincial regulations. Few provinces have legislation that effectively operates in the area of managing hazardous waste disposal in landfills.

There are a number of general principles that should be considered when developing these Federal guidelines. These include[1]:

- sound basic principles enunciated in legislation can reduce rates of waste generation and conversely, increase rates of reuse of hazardous products

- legislation can provide the impetus to improving and expanding the technical and scientific data base. Regulatory controls should not be prepared unless the scientific and technical knowledge is sufficient,

- legislation can provide the impetus for technological progress. This could be accomplished by limiting the choice of available low technical and archaic disposal options,

- legislation can propose rewards through grants or other financial incentives for technological innovations,

Simply stated, legislation can be the main tool by which authorities can regulate the entire 'life cycle' of production/waste generation/treatment and disposal. Legislation, however, can only establish the framework for regulatory control. It must be supported by effective treatment and disposal alternatives.

At the same time, developers of legislation must also be cognisant of the additional costs of both capital works and operation when developing and implementing such legislation.

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1 World Health Organization, 'Management of Hazardous Waste', 1983.

6.1 Federal Roles and Responsibilities

The Federal government has established a role in the development of landfill controls by virtue of its involvement in sponsoring this present initiative. This role resulted from an interest expressed by several provinces.

The Federal government did prepare an overview of landfill guidelines preceeding this subject study. Therefore, there was some prior involvement and interaction between the Federal government and the provinces on this and other hazardous waste management issues.

The Federal role is, however, restricted by the fact that hazardous waste disposal is the responsibility of the province. Although some involvement of the Federal government is supported by the provinces, the degree of involvement is yet to be defined.

Federal involvement in the preparation of landfill controls can be helpful to the provinces, particularly to those provinces without the technical and financial resources. In view of the fact that several provinces are currently preparing or considering comprehensive hazardous legislation, the participation of the Federal government would be timely. However, this participation should be defined in terms of role and responsibility and could consider the following options:

- indirect involvement that would include financial assistance, technical advice or acting as a 'broker' for information exchange and administration between provinces

- direct involvement such as preparation of federal guidelines or codes of good practices, sponsoring background studies or research and development programs,

- a combination of either approach.

Although the development of control options must consider Federal and Provincial roles with respect to regulation and enforcement, both levels of government have a responsibility to protect human health and the environment. Recognizing the importance of this mandate it is recommended the Federal government provide guidance and support to the provinces to ensure:

- a minimum level of environmental and human health protection from the disposal of hazardous waste by landfill,
- comprehensive and uniform landfill regulatory controls and the consistency of application in each province,
- assisting provincial initiatives when requested and where feasible.

The preparation of landfill guidelines or a technical manual of good practice would be an important first initiative by the Federal government in meeting its responsibility and satisfying the above objectives.

6.2 Provincial Roles and Responsibilities

Provincial roles and responsibilities in the development of landfill regulatory controls are more easily identified and described than Federal roles. The provincial role is to regulate and manage hazardous waste from cradle to grave, interpreted to include:

- licencing owners and operators of hazardous waste management transportation, treatment and disposal facilities,
- regulating existing hazardous waste management facilities to ensure compliance with existing legislation and to protect human health and the environment,

- providing or arranging to provide facilities to manage hazardous wastes if necessary,

- preparing legislation and regulations as deemed required to fulfil the provincial role,

- providing a management structure to adequately administer and enforce legislation and regulstions designed to protect the environment and human health.

It is within this series of roles and responsibilities that the implementation framework for development of landfill regulatory controls will be described.

6.3 Implementation Framework

The development of an implementation framework to establish Federal and provincial control options should consider the following:

- the type of regulatory control or public policy desired, i.e. by legislated statute, regulation, guideline, or code of good practice, etc.,

- which government is best suited to enact the regulatory control,

- the legislative process and constitutional framework for promulgating the regulatory control,

- the process that will be followed by the legislating agency in its interface with the public and industry representatives,

- the requirement that the preparation of good regulatory controls is dynamic in nature,

- the urgency of need and the time involved in enacting the resultant regulatory controls.

Table 6-1 provides a comparison of possible control options that might be enacted at the Federal and/or provincial level.

From Table 6-1 several observations can be made with regard to available control options. First, landfill controls should be in the form of a legislated statute or regulation in order to be enforceable and binding to the owner/operator and to the regulator. Secondly, regulatory controls should be developed by the provinces rather than by the Federal government because: it is a provincial responsibility; most of the provinces already have the necessary 'hands-on' ability to enforce waste management regulations; and legislation could probably be developed in a shorter period of time by the provinces.

There are significant differences between provinces that must be considered relative to hydrogeological conditions, climate, population distribution, industry types, waste generation characteristics, and in-place waste management facilities. Landfill controls established solely at the Federal level would have to take all of these into account, making the task a formidable one.

It is believed that the Federal role will not be compromised by provinces developing their own landfill controls, following the Federal government's guidelines. Federal assistance could be advanced to those provinces requesting it relative to public consultation, social economic impact analysis, and technical and scientific guidance.

The United States' experience, during the development of U.S. landfill controls and the subsequent framework for implementation, suggests that authors or architects of such controls must recognize the dynamic and sometimes mercurial nature of the process. In the U.S. they experienced several fundamental changes in philosophy and approach throughout the period of development. As well as their involvement in an extensive public consultation program, they were involved in tough negotiations with the public and private sectors and some litigation.

It is expected that the development of Canadian landfill controls might be similar. The process must be structured to consider public consultation, negotiations and possible revisions.

TABLE 6-1

COMPARISON OF POTENTIAL
REGULTORY CONTROL OPTIONS

Potential Regulatory Control Options	CONSIDERATION	
	Positive	Negative
Federal		
Statute	• consistent and uniform regulation between provinces	• not within the Federal constitutional role • considerable time may be required for preparation and promulgation • would have difficulties recognizing unique characteristics and differences between Provinces • would require more extensive scientific and technical support data.
Guidelines/ Codes of Good Practice	• Federal government could act as broker in terms of guidance and leadership • could be developed in relatively short time frame • would provide minimums for landfilling standards for provinces to consider when adopting legislation/ regulations	• not enforceable • format and content not readily adoptable to legislation by provinces.

Potential Regulatory Control Options	CONSIDERATION	
	Positive	Negative
Provincial		
Legislative Statutes and/or Regulations	• would be specific 'made at home' hazardous waste legislation (which is currently lacking) • are within provincial charter to develop, promulgate and enforce • could probably be enacted in relatively shorter period than federal equivalent • would result in the provinces having ability (and responsibility) to regulate and enforce	• to be truly effective must be accompanied by in-place alternatives to the current practice of disposal by land-filling • hazardous waste legislation is required to support and complement landfill control options • may result in inconsistent approaches between provinces
Guideline/ Code of Good Practice	• shorter time to implement • would require less technical and scientific background	• not legislatively enforceable • provides less guidance to proponent and regulator • would do little to encourage better alternatives to hazardous waste disposal by landfill.

A good deal of time and action is required before landfill controls can be implemented even after they are developed. Waste management legislation must be passed, regulations derived, better alternate waste management systems in place and operating (replacing or reducing the role of landfills). To support these actions we require better waste classifications and definitions of 'hazardous', better technologic/scientific data on problem landfill sites and poor management practices, better waste generation data, and better control on waste transfer monitoring (i.e. a way bill, or manifesting system, etc.)

Recognizing these constraints to the development of landfill control options, it is recommended that the implementation framework should:

- be provincially initiated and legislatively based,
- have Federal assistance (as requested by the provinces),
- allow for fact finding, formulation of alternative policies, consultation with public and private sectors as well as with the public at large through a public consultation program, negotiation and compromise,
- consider and utilize the experience of the United States in the preparation of legislation/regulations.

As a starting point to the implementation framework, the Federal government should develop national guidelines or a technical manual of good practice. These could be prepared by the Federal/Provincial/Territorial Committee. Guidelines would provide the basis for a more comprehensive and legislatively based approach by the provinces and provide a degree of consistency that can be refined and expanded subject to provincial conditions and situations. However, we note that the most comprehensive regulatory controls will not be effective (or enforceable) until technologically better (than landfills) systems for treatment and disposal of hazardous waste are in-place and operating.

This Report, as well as the preceding Problem Assessment Report and the 1983 EPS study entitled 'Landfilling of Hazardous Wastes' provides a background for the development of landfill controls by the Provinces. It is recommended that the Federal/Provincial/Territorial Committee be the catalyst for participation by the provinces in the development of hazardous waste landfill regulatory controls.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides a summary of the conclusions and a number of recommendations arriving from this study. It should be noted that both this and the earlier study on problem assessment have indicated additional information and study is needed to provide the scientific and technical data base necessary for the development of landfill controls.

7.1 Conclusions

- A review of the experience in other jurisdictions including the United States suggests that hazardous waste landfill regulatory controls must be supported and complemented by broader based hazardous waste legislation. Hazardous waste definitions and classifications, as well as manifesting legislation, must be in place to facilitate the implementation of landfilling controls.

- Considerably more (than exists now) scientific and technical work must be undertaken in the subject before developing hazardous waste landfill regulations. This conclusion is supported by reviewing the experience in U.S.A.

- Regulatory controls have been subjected to an extensive public consultation program in the U.S. and the same process should be undertaken in Canada.

- The protection of groundwater resources is an important consideration in developing regulatory standards. In the United States programs for groundwater protection are supported by extensive ground water monitoring requirements.

- There is not a defined or universally accepted approach to the development of landfill regulations. The philosophy and approach to the management of hazardous waste by landfilling varies considerably from jurisdiction to jurisdiction.

- The basis of the regulatory approach adopted by the United States considered both performance and design and operation standards relative to the philosophy of containment.

- Legislation and enforcement considerations are important when developing a control implementation framework.

- The use of alternative (better than landfilling) methods of hazardous waste management have a positive long term effect on the environment. When considering the economics of alternatives, the cost of landfills (problem and otherwise) must include direct (i.e. cleanup) costs as well as indirect (i.e. social) costs. There are significant benefits in terms of costs between 'doing it right' and 'doing it wrong'.

- Landfill regulatory controls are an important requirement in the proper management of hazardous wastes.

- The Federal government has an important role, (albeit an indirect one), in the development of landfill controls. A leadership role combined with the cooperation and participation of the provinces would result in minimum environmental standards and consistency amongst the provinces.

- Certain provinces, notably Ontario are developing comprehensive hazardous waste legislation. These provinces have assembled a considerable amount of data in the Canadian context that would be helpful in the development of landfill controls.

7.2 Recommendations

The following recommendations are directed towards the implementation of a control option to regulate the disposal of hazardous waste by landfill. There are four main options available:

Option 1: For the Federal and Provincial governments to continue on the current courses of activity

The Federal government would continue to assist provinces on request and work within the Federal/Provincial/Territorial Committee. Essentially, this option would see the provinces develop landfill regulations on their own.

Option 2: Preparation of a technical manual or code of recommended practice by the Federal government with input from the Federal/Provincial/Territorial Committee. This manual could be used by the provinces as a basis for developing controls within their own jurisdiction.

Option 3: A combined Federal/Provincial approach to develop and implement landfill regulatory controls. This approach would require commitment by the provinces at the ministerial level, to implement the standards developed as legistlation.

Option 4: Preparation of legislation at the Federal level in the same manner as undertaken in the United States.

In consideration of the need to stimulate development of landfill regulatory controls as soon as possible, Option 2 is the recommended course of action at this time. This would provide a staring point for the provinces and establish the basis for more detailed regulation in the future. If a manual is sufficiently comprehensive, a level of regulation would be possible that would assist both the regulator (i.e. the provinces) and the proponent.

Therefore it is recommended:

- That the 'Items for Consideration' summarized in Table 5-1 of this report be used as the basis for initiating interest and discussion between the Federal government and the provinces, starting with, or working through the Federal/Provincial/Territorial Committee.

- That a Federal technical manual for the disposal of hazardous waste by landfill be developed by this Committee that would assist the provinces in developing more comprehensive legislation.

- That landfill regulatory controls be developed at the provincial level with Federal assistance as required. The regulatory controls should be derived from statutory legislation.

- That the Federal government act as a 'coordinator' between the provinces in developing landfill regulatory controls. This could consist of the Federal government providing expertise and direction to the development of provincial landfill regulations in the context of national guidelines.

- That in the development of landfill regulatory controls by the provinces, the United States' experience be seriously considered as an acceptable legislative, technical and scientific guide. The U.S. landfill regulations resulted from an extensive process of public consultation with industry, environmental groups and the general public. The philosophies, regulatory approaches and the actual regulatory controls developed in U.S. provide an excellent starting point for Canada. Section 2.0 of this report outlines the U.S. experience which we believe is invaluable experience for Canada.

- That the United States' regulatory approach to groundwater protection be adopted when developing hazardous waste landfill regulatory controls in Canada. Protection and maintenance of groundwater resources is a key consideration.

- That a social economic impact analysis not be undertaken at the Federal level since the herein recommended Federal government actions will have no direct economic or social impact. However, the Federal SEIA process should be considered by the provinces when assessing the effect of various proposed regulatory controls. The social impact considerations outlined in Table 5-2 could be the basis for this assessment.

- That the development of landfill regulatory controls should recognize the need for landfilling as an essential component in any hazardous waste management system. However, alternative methods of hazardous waste management should be encouraged and supported so that landfilling is limited to being used for the residues of other higher level treatment processes and for wastes not requiring further detoxification or stabilization before landfilling.

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APPENDIX A

HAZARDOUS WASTE DEFINITION AND CLASSIFICATION

The definition of hazardous waste prepared by the Federal/Provincial/Territorial working committee has been adopted for the purposes of this study. With some minor exceptions, it closely parallels the definition of hazardous waste used in the United States.

The classification of a waste as hazardous must consider whether that waste fits any of the follows:

- the definition of hazardous:

  HAZARDOUS WASTES are those wastes which, due to their nature and quantity, are potentially harmful to human health and/or environment and which require special disposal techniques to eliminate or reduce the hazard.

  WASTE is any substance for which the owner/generator has no further use and which he discards.

- exhibiting the characteristics of:

	(RCRA Equivalent)
- explosiveness	(reactivity)
- flammability	(ignitability)
- oxidation	(reactivity)
- acute toxicity	(toxicity)
- corrositivity	(corrositivity)
- gas in a compressed state	(reactivity)

- listed as a 'waste dangerous goods' in Appendix, Section II, Table I, to:

  Department of Transport, Transportation of Dangerous Goods Act, Chapter 36, Statutes of Canada, 1980, Transportation of Dangerous Goods Regulations, First Unit.

APPENDIX B

SUMMARY OF GUIDELINES FOR, 'CONTROLLED LANDFILLING OF WASTE' - WEST GERMAN FEDERAL ENVIRONMENT AGENCY

Guidelines for 'Controlled Landfilling of Waste' deal primarily with landfill sites which accept solid residential wastes including domestic refuse, bulk refuse and industrial wastes. Landfill sites designed for special wastes or one particular kind of waste are not specifically covered in this guideline.

The guideline addresses construction, operation and closure of landfill sites in respect to the regulatory requirements set forth primarily in the Disposal of Wastes Law (1977) and delegates to the state level for administration, regulation and approval.

Site Selection and Licencing

The Disposal of Waste Law provides that each Lander (or state) has responsibility for the development of waste disposal plans, the provision of assistance in the selection of sites for new facilities, and the final decision concerning the suitability of a specific location for a facility.,

Several documents are required to be submitted in application for approval which describe the need for a landfill, and the properties and facilities affected by the project.

Types of Wastes

Aside from solid residential wastes, a wide variety of wastes can be disposed of in the municipal landfill. The decision regarding which wastes are to be accepted lies with the Lander and is dependent on a number of factors including the location and efficiency of the landfill site, the behaviour of the wastes during operation, and the long term behaviour of wastes in the landfill body.

Depending on the type and quantity of waste, special precautions or conditions may be established for its disposal.

Establishment of Landfill Sites

Guidelines for various components of a landfilling operation have been established. Requirements for access and on-site roads, fencing, the cleaning of tires, and entrance areas and buildings have been prepared.

Naturally, impervious subsoils are preferred for the location of landfill sites, but if a suitable site cannot be found, synthetic liners may be used to prevent the penetration of leachate from the landfill into the subsoil. Design, testing and installation of liner material is discussed.

Leachate collection systems are required for landfills and the leachate collected must be treated accordingly. The subsurface drain layer or drain system may be constructed of highly permeable (coarse grained) soil materials in the case of the drain layer or less permeable (fine grained) material in the conventional drain system.

Groundwater and surface water should be diverted away from the landfill in order to minimize the amount of leachate which has to be treated. Surface water in the landfill should be collected by means of suitable drainage systems and discharged. The quality of the separately discharged groundwater and surface water must be regularly checked.

Wastewater from machinery and tire washing installations should be recycled via a mechanical cleaning system, from which the emanating wastewater should be disposed according to appropriate sewage treatment principles.

Unpolluted stormwater collected should be discharged separately, observing the guidelines on the treatment of stormwater.

Minimum equipment and staffing requirements are set out.

Landfill gas characteristics and effects are identified as well as the precautions which must be taken to prevent damage resulting from generation of methane gas.

Landfill Operation

The normal operation of a landfill site is characterized by placement of the wastes as densely as possible in the landfill immediately upon delivery. The actual method of operation is put forth in a directive which specifies how the permitted types of wastes are deposited on the landfill site and who is responsible for the individual tasks and inspection of work.

Upon arrival, waste delivered must be inspected and record must be made of the types of wastes included. In addition, data concerning such things as weather conditions, leachate monitoring and unusual occurrences are recorded regularly.

Operation techniques for compaction of solid wastes, placement of dewatered sludges from the municipal sewage plants, and placement of industrial sludges in the landfill are described.

Daily covering of wastes in order to prevent nuisances such as wind blown waste paper, infestation by animals, fire and unsightliness of the operating area is recommended where compaction of wastes is not sufficient. The measures necessary to satisfy these concerns are also dependent on the location of the site and the type of wastes deposited.

Landfills should be planned with the possible reduction of noise from the operation of vehicles and machinery in mind.

Depending on local requirements and in particular, the protection of residential and recreational areas, wind protection, noise protection and screening berms made of earth may be necessary. Berm design is briefly outlined.

Treatment of Leachate

Before discharge into water, leachate must be treated in accordance with the discharge conditions.

If technically and economically possible, connection to a sewage treatment plant of adequate size is preferred. If the facility is not available, then the leachate must be collected and transported to a suitable plant or treated on site in oxidation ponds or by other biological treatment methods. The type and quality of leachate is dependent on several factors including the volume, distribution and retention time of the leachate in the deposited waste.

Groundwater Monitoring

The number, location and depth of observation wells for the monitoring of groundwater and their technical specifications are determined site specifically in consultation with technical authorities.

Long Term Care

Relevant standards and guidelines for the recultivation of the landfill are set out by each Lander. Measures for long term care of the closed site include maintenance of the leachate collection, discharge and treatment systems and of the groundwater monitoring wells.

APPENDIX C

BACKGROUND TO COST-BENEFIT EVALUATION
(Section 5.2)

TABLE C-1 Remedial Action Unit Operations

TABLE C-2 Estimated Unit Costs for Surface Sealing Methods and Materials

TABLE C-3 Unit Costs Associated with Revegetation of Covered Disposal Sites

TABLE C-4 Summary of Cut-Off Wall Costs

TABLE C-5 Contaminated Water Treatment Costs

TABLE C-6 Per Unit Costs of Landfill Site Remedial Actions

TABLE C-7 Per Unit Costs of Dedicated Landfill

APPENDIX C

BACKGROUND TO COST-BENEFIT EVALUATION

In this appendix, comparisons were made of costs for remedial work versus 'proper' disposal. By compiling costs of actual work undertaken at problem landfill sites as well as developing hypothetical costs, a sense of magnitude can be appreciated for work necessary to carry out remedial measures. These costs were obtained primarily from United States literature and example.

The figures given in this appendix are applicable only for comparison purposes and cannot be either universally or site specifically applicable. The are, in fact, gross estimates for which the only significance is in the order of magnitude. In this context, the costs must ultimately be related to a particular landfill site with identified problems and refined accordingly. Total costs that must be addressed include feasibility studies, pre-design works, engineering design, operation and maintenance, testing and monitoring. For the most part, these costs have not been addressed in this report, but could be estimated at about 30 percent of the capital costs. Additionally, costs of litigation should be considered in this type of analysis.

Remedial Works

Remedial works are a result of improper activity; in this case, improper landfilling of hazardous wastes. Although generic in terms, remedial works refer to a limited number of alternative actions that can occur at a landfill site, with selected actions dependent on cost effectiveness, technical merit and often, social and political acceptability. In a study conducted by SCS Engineers, a total of 25 remedial action unit operations were identified. These are produced in the following Table C-1.

TABLE C-1

REMEDIAL ACTION UNIT OPERATIONS

Surface Water Controls:

- Surface Sealing with Synthetic Membranes
- Surface Sealing with Clay
- Surface Sealing with Asphalt
- Surface Sealing with Fly Ash
- Revegetation
- Contour Grading
- Surface Water Diversion Structures
- Basins and Ponds
- Dikes

Ground Water Controls:

- Well Point System
- Deep Well System
- Drain System
- Injection System
- Bentonite Slurry Trench
- Grout Curtain
- Sheet Piling Cutoff
- Grout Bottom Sealing

Gas Migration Controls:

- Passive Trench Vents
- Passive Trench Barriers
- Active Gas Extraction Wells

Waste Controls:

- Chemical Fixation
- Chemical Injection
- Excavation and Reburial
- Leachate Recirculation
- Treatment of Contaminated Water

SCS Engineers, Management of Uncontrolled Hazardous Waste Site, 1982, pp 311.

Some of these actions are strictly options, such as surface sealing with synthetic membrane as opposed to asphalt or other impervious materials. Others are complementary. Revegetation and contour grading are other examples. The above list is by no means complete. However, it does provide a basis for analysis of alternatives and an indication of the scope and extent of possible remedial action requirements associated with a problem landfill site.

From this list, a series of activities normally associated with remedial works can be developed. Again, some activities may not be applicable to every remedial works project, but all will be considered and applied dependent on the specific problem. The list is as follows:

- Surface Sealing (Capping)
- Site Grading
- Revegetation
- Surface Water Control
- Leachate Control
- Leachate Treatment
- Surface Water Treatment

The cost estimates, for comparative purposes, are developed on the basis of the above generic action.

Surface Sealing and Capping

Capping of landfill sites using low permeability materials represents one of the most common and effective methods of reducing infiltration into the landfill area thus minimizing leaching potential. Materials and design configurations vary according to the needs of the particular site. For example, a simple clay liner compacted and overlain with vegetation may be all that would be required in a relatively dry climate area. On the other hand, a more sophisticated design incorporating several layers of liner material, possibly clay and artificial membrane, with drain layers and gas venting systems may be more appropriate in other areas.

Aside from the actual installation of capping, there are further maintenance and operation requirements. This would include maintaining the design slopes and vegetation to ensure that landfill cap integrity has not been breached and regular inspection of the cap and the operating gas and infiltration drainage systems. A perpetual monitoring program is also essential to monitor ground and surface waters.

In a study conducted by the United States Environmental Law Institute, a number of remedial works projects were studied to determine the cost of capping[1]. It was found that costs varied with material type, thickness, and related material (such as gravel layers, piping, etc.). This study also found that costs were less dependent on the cap material than on these related works (such as the gravel layer and piping).

The costs for materials and installation varied from $10.25 ($U.S.) to $17.55 ($U.S.) per square metre for capping excluding operation and maintenance costs. This would translate to approximately $220,000 per hectare ($90,000 per acre) ($U.S.). These figures are supported by a study done by SCS Engineers in which an estimate of between $85,000 and $230,000 ($U.S.) per hectare was determined depending on type of capping material used[2].

It should be emphasized that the costs include liner material and associated materials such as protection layers, drainage layers, piping and so on. To identify only the cost of the liner material is a small fraction of the total cost. The following Table C-2 provides liner material costs.

Site Grading

Site grading can be carried out in conjunction with capping activities but is not exclusively complementary. Grading can be done to prevent undesirable surface water ponding or to control slope erosion as well as to prepare the site for final capping.

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1 United States, EPA, Management of Uncontrolled Hazardous Waste Sites, November, 1983, pg. 370.

2 United States, EPA, Management of Uncontrolled Hazardous Waste Sites, November, 1984, pg. 311.

TABLE C-2

ESTIMATED UNIT COSTS FOR SURFACE SEALING METHODS AND MATERIALS

Cover Material and/or Method of Installation	Unit Costs*
Clay hauling, spreading, and compaction	$8.50/cubic yard
Cement concrete (4 to 6-inch layer), mixed, spread, compacted on-site	$6-10/square yard
Bituminous concrete (4 to 6-inch layer), including base layers	$3-5/square yard
Lime or cement, mixed into 5-inches cover soil	$1.50-2.10/sq.yard
Bentonite, material only; 2-inch layer, spread and compacted	$1.40/square yard
Sprayed asphalt membrane (1/4-inch layer and soil cover), installed	$1.50-2.50/sq.yard
PVC membrane (20 mil), installed	$1.30-2.00/sq.yard
Chlorinated PE membrane (20-30 mil), installed	$2.40-3.20/sq.yard
Elasticized polyolefin membrane, installed	$2.70-3.60/sq.yard
Hypalon membrane, (30 mil), installed	$6.50/square yard
Neoprene membrane, installed	$5.00/square yard
Ethylene propylene rubber membrane, installed	$2.70-3.50/sq.yard
Butyl rubber membrane, installed	$2.70-3.80/sq.yard
Teflon-coated fiberglas (TFE) membrane (10 mil), installed	$20/square yard
Fly ash and/or sludge, spreading, grading, and rolling	$1.00-1.70/sq.yard.

*Note different units for volume (cubic yard) vs. surface area (square yard) costs.

Source: United States Environmental Protection Agency "Handbook for Remedial Action at Waste Disposal Sites', 1982.

Site grading costs include equipment and materials and are dependent on types of equipment used, labour, material and haul distance. For a hypothetical site, site grading costs have been estimated at $10,000 per hectare ($U.S.)[1].

This is somewhat less than actual costs incurred at several sites in the U.S. Figures derived by SCS Engineers show an average of about $20,000 per hectare ($U.S.), part of which includes surface water controls. The latter figure was used for the purposes of the cost-benefit evaluation.

Revegetation

Revegetation of disturbed areas of landfill sites should be a standard practice. Vegetation growth helps in sustaining the cover material, reduces erosion potential and allows possibility of an active after use. The following Table C-3 gives some unit costs for revegetation at a hypothetical landfill site[2].

The costs identified in Table C-3 cannot be added since some items overlap while others are dependent on the type and level of revegetation planned for the site. For example, hydroseeding could be used for the entire site or could be interspersed with plantings. From these costs, however, an 'average' cost for an 'average' revegetation activity is estimated to be in the order of $6,200 per hectare ($U.S.) which includes mulching, seeding, trees and shrubs. In addition, annual maintenance costs are estimated to be $250 per hectare ($U.S.).

As in site grading, actual costs at several landfill sites suggest that revegetation costs are over twice the hypothetical cost; in the range of about $19,000 per hectare ($U.S.). For the purposes of comparison in the cost-benefit evaluation, the latter figure was used.

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1 EPA, Handbook of Remedial Action at Waste Disposal Sites, 1982.

2 Ibid.

TABLE C-3

UNIT COSTS ASSOCIATED WITH REVEGETATION OF COVERED DISPOSAL SITES

Description	Unit Costs
• Hydraulic spreading (hydroseeding), lime fertilizer, and seed	$470 per acre
• Mulching, hay	$143 per acre
• Loam topsoil, remove and stockpile on-site; using 200 h.p. dozer, 6-feet deep, 200 feet haul	$0.76 per cu. yard
500 feet haul	$2.92 per cu. yard
• Hauling loam on-site	$1.86 per cu. yard
• Spreading loam, 4-6 inches deep	$0.40-$0.70/cu.yard
• Plant bed preparation (unspecified), 18 inches deep, by machine	$6.21 per sq. yard
• Hydraulic Seeding and fertilization of large areas, with wood fibre mulch	$0.33 per sq. yard
• Mulch, hand spread 2 inches deep, wood chips	$1.01 per sq. yard
• Liming slope areas	$220 per acre
• Fertilizing, level	$200 per acre
slope	$270 per acre
• Seeding, level	$325 per acre
slope	$395 per acre
• Jute mesh, stapled (erosion control)	$0.65 per sq.yard
• Sodding, in East, 1-inch deep, level	$3.10 per sq.yard
slope	$3.42 per sq.yard

Surface Water Control

Surface water control is used to divert and/or collect run-off from creating further impact on the landfill. Remedial works include diversions, piping, ditching, berming, retention pond, etc. Type of works required would be a direct function of each individual site and costs, and unlike other items, would be virtually impossible to estimate. For the purposes of the cost-benefit evaluation, an allowance of $2,500 per hectare ($U.S.) was used.

Leachate Control

Leachate control can be effected by a number of methods including installation of purge wells, interceptor ditches and cut-off walls. Among these, the most effective has been cut-off walls.

Cut-off walls are often used to isolate a particular landfill site from uncontaminated groundwater entering the flow net of a problem site or to retard the contaminated groundwater from escaping the site. Cut-off walls are normally used in conjunction with other remedial works, such as pumping and treatment of contaminated leachate. Although once claimed to be a permanent solution to the problem of leachate migration, it is now considered only a temporary means of leachate control. Leachate production must be managed over the long term of the landfill site.

There are various materials and methods used to construct a cut-off wall including bentonite slurry mixes to clays and asphalt based proprietary materials. The manner of construction includes the use of trenches to vibrating beams.

Cut-off walls installed at a number of remedial works sites were investigated for costs by the Environmental Law Institute[1]. These costs varied from $2.26 per square metre to $319 per square metre ($U.S.) depending on the type of material, depth and installation method and whether or not the excavated material required further disposal.

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1 United States, EPA., Management of Uncontrolled Hazardous Waste Sites, November, 1983.

The following Table C-4 summarizes cut-off wall costs for 5 sites in the United States as well as a theoretical estimate prepared by SCS Engineers, a U.S. consulting firm. Considering this Table, the cost to construct a cut-off wall is estimated to be $100,000 per hectare ($U.S.).

TABLE C-4

SUMMARY OF CUT-OFF WALL COSTS

Site Name	Date	Cut-off Wall Type	Unit Cost
Anonymous Site A	1980	Asphalt, Sand, Concrete, Water Emulsion	$7 per sq.ft. ($75 per sq. metre)
Anonymous Site A	1982	Asphalt, Sand, Concrete, Water Emulsion	$14 per sq.ft. ($150 per sq. metre)
Anonymous Site B	1980	Asphalt, Sand, Concrete, Water Emulsion	$5.60 per sq. ft. ($61 per sq. metre)
Anonymous Site C	1981	bentonite slurry	$29.59 per sq. ft. ($319 per cu. metre)(d)
Anonymous Site D	1983	local clay	$1.42 per sq. ft. ($15.13 per sq. metre)
Anonymous Site E	1980	local clay compacted in lifts	$0.21 per sq. ft. ($2.26 per sq. metre)
'SCS Estimate'	1980	bentonite slurry	$4.28 - $7.56 per square foot

Source: United Stated, EPA., 'Management of Uncontrolled Hazardous Waste Sites. November, 1983.

Water Treatment

Treatment of leachate and contaminated surface water is highly dependent on treatment process and related waste quantities requiring treatment. A study done by the Environmental Law Institute is summarized in Table C-5 and indicates treatment costs for 8 landfill sites in the United States ranging from $0.00015 to $1.1 per litre ($U.S.). This wide range in actual costs does not provide direction in estimating even an average cost.

Another study by SCS Engineers shows a range of costs for treatment of contaminated water to vary between $150,000 to $250,000 per hectare ($U.S.) with operating and maintenance costs running between $12,000 to $18,000 per hectare ($U.S.) per year[1]. $200,000 per hectare ($U.S.) was used as an average cost in the cost-benefit evaluation.

Summary - Remedial Works

Table C-6 summarizes the per unit costs of landfill site remedial actions. These costs were applied in the cost-benefit evaluation as the measure of 'doing it wrong'.

Table C-6 includes only those remedial actions which were typically undertaken at many of the remedial action sites in the United States. Therefore, the costs identified are average and without regard for many of the site specific situations encountered in a clean-up action. These costs are adequate for comparative purposes, but should be recognized as probably low since additional remedial actions at a site would often increase unit costs signficantly.

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1 United States UPA, 'Management of Uncontrolled Hazardous Waste Sites', November, 1982.

TABLE C-5

CONTAMINATED WATER TREATMENT COSTS

Site Name	Date	Treatment Technology	Contaminant	Quantity Treated	Unit Cost
Anonymous Site A	1981	On-Site advanced oil/water separator	PCB/Oil	1,000-1,500 gallons (3,785-5678 l)/month	$2.70-4.6/gal. ($0.73-1.10/l)
Anonymous Site B	1982	Off-site Commercial Treatment	Cyanide	9,425 gallons (35,674 l)	$1.35/gallon ($0.036/l)
Anonymous Site C	1980	On-site carbon clarification, air stripping	mixed solvents, PCB	7.8×10^6 gallons (2.9×10^9 l) over 6 month period	$0.26-0.40/gal(b) ($0.068-0.10/l)
Anonymous Site D	1979	On-site carbon, pea gravel/line filtration	Pentachlorophenol (PCP)	2×10^6 gallons (8×10^6 l) over 1 month period	$0.10-0.18/gal. ($0.026-0.048/l)
Anonymous Site E	1983	On-site Biodegradation	methylene chloride, butanol, acetone	13,680 gallons (51,779 l)/day	$0.0165/gallon ($0.0044/l)
Anonymous Site F	1982	Off-site POTW (c)	hexavalent chromium	273,000 gallons (1.03×10^6 l)	$0.008/gallon ($0.002/l)
Anonymous Site G	1979	Off-site POTW (c)	Pesticides (atrazine, alachlor)	9×10^7 gallons (3.4×10^8 l) over 5 month period	$0.00056/gallon ($0.00015/l)
Anonymous Site H	1982	On-site Granular Activated Carbon (reverse pulse)	Pesticides (DBCP)	$1.5\text{-}2.6 \times 10^8$ gallons ($6.8\text{-}9.8 \times 10^8$ l)/year	$0.0005-0.0011/gallon ($0.00013-0.00029/l)
'SCS Estimate'	1980	On-site 'Chemical, biological and/or physical'	'contaminant'	4.3×10^7 gallons (1.6×10^8 l)/year	$0.0012-0.0022/gallon ($0.00032-0.00058/l)

SOURCE: United States EPA, 'Management of Uncontrolled Hazardous Waste Sites,' November, 1983.

Dedicated Hazardous Waste Landfill

A landfill dedicated to hazardous wastes will be characterized by certain works which distinguish it from municipal type landfills. Often called secure landfills, these landfills would normally have liners of either an artificial membrane or constructed of natural materials (e.g. clay), leachate collection systems, extensive groundwater and surface water monitoring system, final capping or surface sealing and a post-closure plan.

Table C-7 provides an estimate of costs to establish and operate a secure landfill site. These costs do not appear to be significantly different than the costs associated for remedial works estimated in Table C-6. A first conclusion might, therefore, be that the additional up-front costs associated with a secure landfill are not warranted on a cost basis and that these costs are in the order with those costs associated with landfill remedial works. What this argument fails to consider are some significant quantifiable and non-quantifiable aspects such as:

- significant cost items such as compensation payments and lawsuit claims are not concluded,
- certain health and environmentally related impacts cannot be adequately accounted for in a cost-benefit analysis,
- the social acceptability of 'doing it right' versus 'doing it wrong' is not debated since it is difficult to quantify,
- all or a significant part of the cost of secure landfill establishment and operation is borne by the waste generator. In contrast, the cost of many landfill remedial programs have been the responsibility of the public.

TABLE C-6

PER UNIT COSTS OF LANDFILL SITE

REMEDIAL ACTIONS[1]

Action	Per Unit Cost (Hectare)
Surface Sealing and Capping	
• includes the cost of hauling, spreading and compaction of EPA defined cap	$220,000.
Site Grading	
• includes the cost of hauling and spreading, materials, equipment and compaction testing	$ 20,000.
Revegetation of Site	
• includes the cost of mulching, seeding, the planting of trees and vegetation, topsoil and fertilizer	$ 15,000.
Surface Water Diversion and/or Collection	
• includes the cost of ditching, piping, system and pond construction, materials	$ 2,500.
Leachate Control	
• includes the cost of materials and construction of cut-off walls	$100,000.
Treatment of Contaminated Surface Waters and Treatment of Contaminated Groundwaters	
• includes the cost of collection and treatment	$150,000 to $250,000.
	$560,000.

1 These cost estimates are only gross approximations based on available published data from the United States EPA and are only used for the purposes of comparative analysis. Costs do not include engineering, landfill operation or site maintenance.

TABLE C-7

PER UNIT COSTS OF DEDICATED
LANDFILL DESIGN AND OPERATION

Action	Per Unit Cost Per Hectare
Landfill Site Area and Buffer Zone	$ 10,000.
Site Preparation	
• grading, excavation	$ 20,000.
Leachate Management System	
• collection and treatment	$ 50,000.
Liner Requirements	
• natural	$ 70,000.
• synthetic	$200,000.
Storm Water Management	$ 2,000.
Monitoring	
• surface and groundwater	$ 2,000.
Other Site Capital Works	
• weigh scales, equipment, laboratory, storage areas, etc.	$ 50,000.
Site Closure	
• capping, revegetation, etc.	$130,000.
Post-Closure	
• inspection and maintenance	$ 5,000.
	$540,000.

Does not include landfill operations or site maintenance.

The illegal, hazardous waste dump in King Township, Ontario, is a case in point. The owners of the land, having been found guilty of illegally dumping hazardous waste in an unlicenced site, spent about $80,000 in an inadequate clean-up effort. The Ministry of the Environment have so far spent in excess of $700,000 with the final cost for remedial works yet to be determined.

Therefore, in comparing Table C-6 and C-7, a significant allowance must be made for unknown and non-quantifiable costs. This is particularly telling when reviewing actual site cleanup costs of problem sites in the United States as described in Section 5.2 of this report.